COLE & ELMAN

TEXTBOOK of SURGERY

Seventh Edition

COLE & ELMAN

TEXTBOOK of SURGERY

WARREN H. COLE, M.D.
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with

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Foreword by EVARTS A. GRAHAM



Appleton-Century-Crofts, Inc.
New York

559–13

Library of Congress Card Number: 59–5263

PRINTED IN THE UNITED STATES OF AMERICA

To

DR. EVARTS AMBROSE GRAHAM

and

DR. ROBERT ELMAN

Who have exerted great influence on my professional career. Their loyal friendship and inspiration will always be remembered.

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Preface

Since publication of the last edition we have suffered an irreparable loss in the death of Robert Elman. His broad knowledge of the field and his many attributes as a splendid teacher of surgery were vital to the success of this volume. He contributed a great deal to this revision, but he died before final copy could be prepared. Our hope is that we have maintained the same high standard of excellence which has characterized the contributions of Doctor Elman to earlier editions.

This edition has been completely revised and completely rewritten with new material. Nine new chapters and 297 new figures have been added. The book begins with a brief history of surgery written by Doctor Nathan Womack. Dr. Oscar Creech and Dr. E. T. Krementz have contributed a chapter dealing with laboratory tests and aids. Traumatic injuries are increasing in number, and a chapter on the systemic reaction to trauma by John Howard has been added to the book. Cancer incidence, etiology, dissemination, and principles in diagnosis and treatment are discussed anew. Two new chapters on the heart and great vessels, one dealing with congenital lesions and the other with acquired lesions, by Michael De Bakey and his associates are included for the first time. Medical conduct and ethics are explained to the student.

We have made great changes in the remaining chapters. Much new material has been added by many new contributors.

Physiology has been stressed and the needs of the student have been continually kept in mind. Nonsurgical treatment is described in detail, and the principles of operative treatment are presented. Numerous illustrations of gross specimens and photomicrographs will be found throughout the text.

We are indebted to many friends for valuable assistance in preparation of various chapters. Among them are Dr. Leo Sachar, Dr. Arthur Stein, Dr. Myron Wheat, Dr. Frank Richards, Dr. James Hunter, and others. We wish also to express our sincere appreciation to Miss Josephine Magista, Mrs. Ruth Scapino, Mrs. Doris Peterson, and Mrs. Florence Bagnall for their untiring secretarial assistance. Mr. Hooker Goodwin and his staff in the Illustrations Studios have contributed many new drawings. The publishers have at all times manifested the utmost cooperation in preparation of this revision.

WARREN H. COLE, M.D.

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Foreword

The object of this book has been to present a *systematic survey of the field of surgery.* Obviously in the space of one volume an attempt could be made only to deal with those aspects of surgery which would seem to be the most important. It is not easy to make a satisfactory selection of those topics which actually are *the most important. Different surgeons* would doubtless have various opinions concerning what subjects actually are the most important and, therefore, deserve the most emphasis. Especially would this be true in regard to many of the conditions which have now, by more or less com*mon consent, fallen into the realm of* some one of the specialized subdivisions of surgery. This book reflects the effort which has consistently been made to give rather more information about those matters with which every general practitioner should be familiar than to attempt *to cover the entire field of surgery.*

With the enormous development of surgery during the present century it has become increasingly more difficult to prepare a work which could properly be called a *Textbook of Surgery.* For such a book should be small enough *to be encompassed in one volume and at the* same time be sufficiently comprehensive to give the student a reasonable amount of information concerning those surgical conditions with which every medical student should be more or less familiar. To prepare such a work has been a *challenge* which *many* authors have accepted. Many of the results have been excellent but there is a rather widespread feeling among surgical teachers that the ideal text has not yet been written. Perhaps it never will be. Certainly no book could hold a first rank place for a long period of *time without frequent revisions* because of the necessity to incorporate within it the rapid changes in points of view, in methods of diagnosis, in the treatment and even in the conceptions of what diseases may properly be regarded as having surgical aspects. As one reviews the changed conceptions concerning what conditions have surgical aspects he is forced to the realization that nowadays there are scarcely any diseases in which the advice of the surgeon may not be sought. Within the years of the present century almost incredible changes have occurred. Pulmonary tuberculosis, certain aspects of nephritis, heart diseases, malignant hypertension, cancer of the lung, hyperinsulinism, hyperparathyroidism, to mention a few, have already been transformed from conditions which presumably had no surgical implications to ones which now demand space and attention in any *comprehensive work on surgery. Endocrinology,* one of the newest medical sciences, is now, from a therapeutic aspect, largely a surgical problem. When one contrasts the present scope of surgery, therefore, with its scope when it was largely the practice of external medicine, he of necessity *realizes that the writing of a satisfactory text*book becomes increasingly difficult as time goes on.

Dr. Cole and Dr. Elman have appreciated that, because of the necessities involved, a textbook of surgery should have certain qualities. In *order to encompass the material in a single* volume conciseness is a prime requisite and, of necessity, many things have to be omitted which it would be desirable to have in the book. It seems to me that they have carried out their object in a remarkable manner. The various surgical conditions are excellently described as are also the accepted methods of treatment. On the other hand, they have very rightly in such a book paid but scant attention to the conceptions and the treatment of the diseases in question which are too new to have been given a sufficient trial. Moreover, by eliminating many relatively unimportant details, the authors have felt justified in expecting the student to become familiar with all of the material included in the text. Obviously, of course, no limits should ever be placed on the amount of reading of current and other literature; *indeed, further outside reading* is demanded of the student. To aid him, an extensive bibliography has been included. Elaborate descriptions of operations are not given because such material is presented in the various systems of surgery and it hardly deserves a place in a book of this kind. The principles involved in the various operative procedures, however, are stated. It is futile to attempt to make an undergraduate student a finished surgeon. To accomplish that purpose years of postgraduate study and experience are required. Nothing, therefore, would be gained by including within this book extensive and detailed descriptions of operations.

The book should be found to be very helpful, not only to undergraduate students but also to general practitioners who desire to obtain in a concise manner information about many of the advances which have been made in surgery. Even the experienced surgeon will find the book helpful for the same reason.

EVARTS A. GRAHAM

COLE & ELMAN

TEXTBOOK of SURGERY

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A BRIEF BACKGROUND OF SURGERY

NATHAN A. WOMACK

One might well ask why, in a textbook of contemporary surgery, space should be devoted to a consideration of surgery of the past, a surgery that has already been accepted and become commonplace, or concepts and principles that have been thrown into discard. Many reasons could be suggested for such a study, any one of which would be adequate for the thoughtful and critical student and perhaps none of which would satisfy the most pragmatic. The latter could say, and occasionally with good justification, that to learn only what is known now will enable him to practice adequately the surgery that should be done now. But what is known now? What are the things we should believe to be fact and what are those we should not accept? Certainly we learn very quickly that the opinions of those in authority are ephemeral indeed. We thus can learn contemporary surgery, but how can we evaluate it? How can we be assured of its truth?

Speaking in a different context, Lord Acton once said, "The living do not give up their secrets with the candor of the dead; one key is always excepted and a generation passes before we can insure accuracy. Common report and outward seeming are bad copies of the reality as the initiated know it. . . . The use of history turns far more on certainty than an abundance of acquired information." One has only to glance through the pages of a surgical journal a decade or two old to see the truth in this statement.

We can say then that a firm background in the knowledge of the past, both in general and in specific subjects, will give us a clearer understanding of the present. We can see the path by which the present was reached. On rare occasions we are enabled to see even a few steps into the future.

The story of surgery differs from that of the arts or of politics or of the law in that it has been slowly cumulative. Even so, it has not developed as a cold, experimental discipline but has often been discontinuous. There have been periods of close association with political and ecclesiastical history, many times to the detriment of surgery, rarely to its advantage. It has nourished itself on wars. It has suffered from the numerous restraints on education. Einstein has said of great advances in scientific theory that they occur in the manner of quantum jumps, being discontinuities rather than logical progressions. And so it has been with surgery. These jumps have occurred during those periods of a "disregard for inherited sanctions" where little has been taken for granted.

In studying the past, one sees that surgery is not a simple vocation concerned only with the sale of services. In the deep urge to relieve the pain and torture of mankind there appears constantly a tremendous idealism rising above the commonplace of the day and giving hope to all mankind. Of such has surgery been built. Here are both scientific values and human values of a high order indeed. Here is the unbridled triumph of the individual in pursuing these efforts. This is the heritage, then, that the past gives the con-

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mporary surgeon. It is well worth a serious udy.

This brief chapter can give the reader all o little of this heritage. The good historian ust always consult intimately the source aterial just as the good scientist consults e source background of his experimental oblem. For the busy surgeon this is impos- ble. It requires time and a knowledge of lan- iages, modern and ancient, that few of us ossess. There must be available an unusual orary as well as detachment and patience. bviously then, in this chapter we will be le to consider only a few facets of our oblem.

In most civilizations, surgery seems to have eceded internal medicine. This is natural cause of the immediacy of physical trauma. ere, help of a practical nature could be ven without dependence upon philosophical eculation. Surgery required only careful servation and such observations, condi- oned as they were by pain, did not require o high a degree of intellectual development. nimals will keep an injured part at rest and, possible, a dirty wound open.

PRIMITIVE SURGERY

Human skulls in which circular fragments bone have been removed as if by trephine ive been found dating back to the Neolithic Polished Stone Period. Evidence of heal- g of the bone shows that there were at least casional instances of survival. It has been sumed that such operations were performed r headache and for epilepsy in order to al- w egress of evil spirits. On the other hand, is known that buttons of bone were used as nulets. Therefore, there may have been ther reasons, perhaps of a religious nature, r the performance of this operation. Cer- inly with the origin of serrated flint instru- ents, surgical procedures became manifest.

It was the feeling of Ruffer that the major- y of trephine openings were made during fe and that those resembling post-mortem rocedures were in patients who died during r shortly after the procedure. Of interest are e skulls in which more than one trephine pening is found in various states of healing. his suggests the probability that the trepan- tion was done for disease, perhaps headache, that was not cured by the first operation. Certainly one must question the concept of Broca, that the skull was trephined on young epileptics or mad subjects to rid them of some "demon," for if Neolithic man possessed the same ideas as those people in more recent times who have been found to have a comparable type of civilization, the epileptic and the insane were considered holy and held in high estate. Trephined skulls have been identified not only in western Europe, but in Switzerland, Romania, Poland, Denmark, Germany, and Sweden. There is no indication that the Chinese or Hindus ever practiced such a procedure, nor have such skulls been uncovered from the Egyptian, Greek, or Roman cultures. In the Western World, previous to the arrival of the Europeans, the operation was unknown among the Indians of the north but was practiced in Mexico and Central America and especially in Peru.

These findings, then, are not limited to any particular culture but seem to be more or less universal. Whether these "elemental ideas" sprang spontaneously in these various groups, a "convergence concept" as introduced by Bostian, or whether by "Convection" as sponsored by Ratzel is a problem for ethnologists and need not concern us here. They all, for the most part, seem to be related to superstition or basic religious notions concerned with spirits, both good and evil, that directed the destiny of man.

Another operation that may have been a superstitious rite is that of amputation of the fingers, noted in the late Paleolithic period perhaps 25,000 years ago. Garrison states that over 200 silhouettes illustrating this procedure have been found on walls of Paleolithic caverns in Spain as well as elsewhere. There is always hazard involved in the interpretation of previous cultures from the vantage point of our own. Some of these practices may not have been entirely a religious ritual. We see an exception insofar as amputation of the foot is concerned in Lawson's study of the early North Carolina Indian (1714):

> The Iroquois or Sinnegars are the most War-like Indians that we know of being always at War, and not to be persuaded from that Way of Living by any Argument that can be used. If you go to

persuade them to live peacably with the Tuskeruros, and let them be one People, and in case those Indians desire and will submit to them, they will answer you they cannot live without War, which they have ever been used to; that if Peace be made with the Indians they now war with all, they must find out some others to wage War; for them to live in Peace is to live out of their Element, War, Conquest, and Murder being what they delight in, and value themselves for. When they take a Slave and intend to keep him to work in their Fields they flea the Skin from the Setting on his Toes to the middle of his Foot, so cut off one-half of his Feet, wrapping the Skin over the Wounds, and healing them. By this cruel Method, the Indian Captive is hindered from making his Escape, for he can neither run fast or go anywhere, but his Feet are more easily traced and discovered. Yet I know one Man who made his Escape from them, though they had thus disabled him, as you may see in my Journal.

In recent years the operation of transmetatarsal amputation has been reintroduced into surgery albeit for entirely different indications.

That medicine and surgery had become well established in western Asia more than 2,000 years before Christ is revealed in the discovery of the *Code of Hammurabi*, written around the twenty-first century before Christ. This Code also gives evidence of the fact that the surgeon's fee and the character of his surgery had become a concern of the government. Portions of the Code have been translated as follows by Leonardo:

> If a physician shall cause on anyone a severe operative wound with a bronze operating knife and cure him, or if he shall open a tumor (abscess or cavity) with a bronze operating knife and save the eye of the patient, he shall have ten shekels of silver; if it is a slave his owner shall pay two shekels of silver to the physician.
>
> If a physician shall make a severe wound with a bronze operating knife and kill him, or shall open a growth with a bronze operating knife and destroy the eye, his hands shall be cut off.
>
> If a physician shall make a severe wound with a bronze operating knife on the slave of a freed man and kill him, he shall replace the slave with another slave. If he shall open an abscess (growth, tumor, cavity) with a bronze operating knife and destroy the eye he shall pay the half of the value of the slave.
>
> If a physician shall heal a broken bone or cure diseased bowels, he shall receive five shekels of silver; if it is a matter of a freed slave, he shall pay three shekels of silver; but if a slave, then the master of the slave shall give to the physician two shekels.

From this we can infer that a practice of surgery existed. It is also apparent that the surgeon was not separated from the physician, at least in title. The true nature of the practice of medicine in ancient Babylonia exists only in a few scant fragments of tablets that have persisted and in copies of tablets of that period that were made in the Assyrian Empire around the seventh century before Christ. As fragmentary as this material is, a good general concept of the type of medicine practiced can be obtained. Treatises were related to diseases of certain areas such as the head and the digestive organs. There was an extensive materia medica and remedies were applied locally, given by mouth, or inserted as suppositories. These remedies seemed to have been used without specific indications, many being prescribed for the same disease. All medicine seems to have been permeated with superstitions and primitive folklore. Knowledge of anatomy or physiology must have been limited. Of great interest is the fact that none of these tablets relating to early Babylonian medicine refers in any way to surgery other than the Code mentioned above. Some future excavation may bring additional discoveries to light.

In sharp contrast is the picture of surgery in early Egypt. In this older civilization, surgery was farther advanced. Several papyri relating to medicine in early Egypt have been discovered and translated, and each contributes to our understanding of the period. Until recently, knowledge was limited to the information based on the Papyrus Ebers, the Berlin and London Papyri, and the Papyrus Hearst, along with fragmentary portions of several smaller special documents. Interestingly enough, the compilations were all written in the period from the early eighteenth to the sixteenth century before Christ. All of these have been valuable.

In 1930 Breasted published his translation of Papyrus Edwin Smith, which apparently is a transcription of a document from the period of the Old Kingdom about 3,000 years

before Christ. It could easily have been written originally by Imhotep, and Breasted feels that such was probably the case. As such it represents the earliest known treatise on surgery. It undoubtedly represents also a portion of a much larger series of dissertations as it for the most part treats only trauma. Forty-eight cases are described in a systematic arrangement, beginning with the head and extending downward, considering first the less serious injury and later the more serious one. This is not a document of recipes and magic. Here one sees logical conclusions arrived at from facts observed on physical examination and opinions based on considerable clinical experience. Such an approach today is commonplace; for that period it is startling, since almost 5,000 years were to elapse before trauma was again to be treated so intelligently.

Examination consisted of looking at the patient, obtaining a history of the injury, and then determining the extent of the injury. The wound would be probed, the patient instructed to make certain motions, and from these observations a diagnosis established. If the prognosis was favorable, certain treatments of a mechanical nature would be carried out. If the prognosis was indubitably fatal, as in compound wounds of the skull involving the brain, no treatment was recommended. In 13 of the cases described after determining the facts from such observations, a diagnosis was determined logically. "These are the earliest surviving examples of observations and conclusions, the oldest known evidences of an inductive process in the history of the human mind" (Breasted). Here, for the first time, we note a knowledge of the nervous control of muscle contraction, the recognition of the brain not only as an organ but as the seat of the mind, the action of the heart, and the relation between the heartbeat and the pulse rate, information that was not to appear again in human writings for 2,500 years. In Case I, counting of the pulse seems to be described, but this is difficult to understand because of the Egyptians' lack of methods by which to measure short periods of time. Even the water clock had not been developed. The earliest known counting of the pulse with a known time measurer was not to be done until Herophilus in the third century before Christ.

While paralysis of certain muscles was noted following injury to specific areas of the brain, apparently no effort was made to explain the quadriplegia that followed fracture dislocation of the cervical vertebrae. The methods of treating a fractured nose and dislocation of the jaw are classical and are used even at the present time.

Perhaps the single greatest achievement in the history of medicine has been the exclusion of demons, spirits, and sin from the explanation of the origin of disease. Not until this was done could true cause–effect relationship be sought for and established. This has been, and even at times still is, a long and laborious task for society to achieve. It is important, therefore, to note disease described by these early Egyptians as "something which his flesh engenders," denoting the separation of disease as well as accident from the demoniacal.

Perhaps the most impressive technical development lay in the treatment of soft tissue injury. A clean, incised wound was sutured. Whether the surgeon learned the use of the suture from the embalmer or vice versa is of no great importance. The value of the immediate closure of a clean wound without the application of any type of ointment or concoction represents accuracy in observation of a high degree. Irregular, ragged wounds were brought together with adhesive strips. These strips were made of linen cloth to which an adhesive gum was applied, and the surgeon is, on several occasions, cautioned to apply two at the same time, exerting traction with each in opposite directions. Large, gaping wounds with loss of substance were not closed. Apparently the damaging effect of dead space had been observed. It was advocated that such wounds be filled with fresh meat and a bandage applied. This was to be removed in 24 hours and the wound filled with honey. It is difficult to imagine a more sterile covering than these two dressings would afford.

The value of fixation in the treatment of fractures was well recognized, although traction was not completely appreciated. The use of reed splints as well as of a rigid type of plaster made from linen bandages impreg-

nated with resin for fixation of fractured sites was common. Fractures were apparently common. In a study of Egyptian cemeteries of a later date from which between 5,000 and 6,000 bodies were exhumed, one person out of every 32 was noted to have had a fractured bone. Shortening was frequently seen, although nonunion and evidence of infection were practically never observed. Since many of these fractures were of the tibia and fibula, at least a considerable number of them must have been compounded.

This period of Egyptian medicine was not without its specialization. Junker describes a tombstone of a palace physician at Gizeh during the period of the Old Kingdom (circa 2500 B.C.). This man, whose name was Iry, possessed among other titles "palace eye physician, palace physician of the belly, and guardian of the anus."

What knowledge of surgery existed in the Old Kingdom other than that of trauma we as yet have little way of knowing. From the fragments of information that have come from studies of other papyri, particularly that of Ebers, it is probable that other phases of surgery had not developed to such a high degree. This held true for what would be considered internal medicine also. Perhaps it was for this reason that such an excellent achievement in the surgery of trauma was to undergo a considerable degree of decay. Mysticism and magic were always in the background and, where ignorance of natural laws was profound, they could easily make their appearance and achieve an ascendency. The late eminent historian of medicine, Henry Sigerist, has postulated that the level of culture of a society has always been reflected in the state of medical knowledge and practice of that society. Such seems to have been true in Egypt, for with a decline in surgical and medical knowledge, there was also social and political decay.

This decline, however, was not sudden nor was it complete, for Egyptian surgery again came to the front during the period of the Alexandrian School many centuries later. During this long interim there is evidence of the continued respect in which medicine was held. Interest in Egyptian physicians was shown by Darius I of Persia in the establishment at Sais around 500 B.C. of what seems to be the first school of medicine under royal patronage. Students were selected, according to Uzahorresenet, the High Priest and "Chief Physician" who organized the school, "from among the sons of men of consequence, no sons of the poor were among them. I placed them under the hand of every wise man. . . . I equipped them with all their needs, with all their instruments which were in the writings according to what was in them aforetime. His Majesty did this because he knew the value of this art, in order to save the life of everyone having sickness. . . ."

That there were physicians in Egypt who were not priests we learn from the Bible in Genesis 50, 2: "Joseph commanded his servants the physicians to embalm his father: and the physicians embalmed Israel." The Bible also gives us a bit of insight into the nature of ancient Hebrew medicine. The ancient Hebrews, for the most part, looked upon disease and accident as punishment by a divine authority because of some previous transgression. As a result, it was only natural for the practice of medicine to be a function of the priests, and such for the most part it was. Under such authority, public health methods could be developed effectively and often were. There was little impetus for progress in surgery, however. That there were other physicians than priests among the Hebrews may be noted in Second Chronicles 16, 12–13: "In the thirty-ninth year of his reign Asa was diseased in his feet, and his disease became severe; yet even in his disease he did not seek the Lord, but sought help from physicians. And Asa slept with his fathers. . . ." It was, however, probably not until after the Alexandrian period that medicine as a separate discipline was studied by the Jews.

GREEK SURGERY AND MEDICINE

Let us now turn to the development of surgery and medicine in Greece. Whether there was any interplay between the Egyptian and early Cretan civilizations insofar as surgery is concerned we have no way of knowing. It is of interest that the god of Greek medicine, Aesculapius, has been considered by some to have been the same as the Egyptian god Imhotep, who apparently actually lived. In the

Homeric poems, Aesculapius is treated not as a god but as an extremely learned and successful physician with two sons, Machaeon and Podalirius, who were both surgeons and soldiers. The Homeric respect for the warrior was matched by equal respect for the surgeon who dressed the wounds. Many of these wounds are described in detail as are the methods for care. They relate in particular to the difference in wounds produced by a sword or spear and those produced by an arrow. The latter wounds were considered less serious, and methods of extracting arrowheads were described.

Following the period of Homer, little of significance occurs in Greek surgery until the advent of the Hippocratic writings. During the sixth and fifth centuries before Christ, there had grown up in Greece numerous temples of health erected to Aesculapius; of the 50 or 60 known to have existed, the most famous were those at Cnidos and Cos. These temples were presided over by priests; and descriptions of their treatment of patients suggest a combination of mysticism, burnt offerings, and baths. In the areas around these temples, medical families would settle, persons who were not priests but who developed their own methods for the care of the sick. There seems to have been little or no competition for patients between these two groups, one limiting itself to prayers and seeking miraculous cures; the other, a lay group, making observations, collecting information, and suggesting logical therapy. Fortunately, the groups at Cnidos and Cos put many of their doctrines into writing. While Cnidos and Cos have often been referred to as "schools," they probably are best thought of as groups of persons, often of the same family, who pursued similar concepts, rather than as true "medical schools." The best-known pupil of Cos was Hippocrates. The collected works of Hippocrates have been translated into English by several authors and are now easily available. Just which of these treatises were written by Hippocrates himself is not known, and speculation as to authorship has been rife since the time of Galen. Since Hippocrates lived during the Golden Age of Greek civilization, it is possible to date several writings as preceding his time. As a matter of fact, "The Oath of Hippocrates" has been considered by some to have been of earlier origin; but since it is so completely in keeping with the ethics of the period, there is no question as to where it belongs.

The Hippocratic contributions to surgery are tremendous. There is not enough space in this chapter to consider them in detail, but it is hoped that the student sometime in his life (the sooner the better) will read them in their entirety. If he does, he will be impressed with an extensive clinical experience, accurately and modestly recorded. Straightforward observations, simple and logical deductions, and humility are seen time and time again. Hippocrates described no miraculous cures, often giving a gloomy prognosis. He apparently wrote, not to impress anyone, but to give a simple and honest statement of what he knew, a refreshing feat among medical writers of all times. Perhaps a majority of his Aphorisms as we view them today are false, many absurd, some even mischievous—such as VII-87, "Those diseases which medicines do not cure, iron (the knife) cures; those which iron cannot cure, fire cures; and those which fire cannot cure, are to be reckoned wholly incurable." On the other hand, his treatment of congenital clubfoot is remarkably modern. Fractures were treated with both splints and a type of rigid bandage. The principle of traction was well recognized in reduction of fractures and dislocations, although the apparatus used was often crude. Examination of the injured part is more clearly described and the lesion more minutely classified than in the Egyptian period of the Old Kingdom. In the treatment of soft tissue injuries, however, the Egyptians' methods, used 2,500 years earlier, do not fare too badly in comparison.

The consideration of the whole patient appears quite clearly in the Hippocratic Corpus. Nowhere is this better seen than in the Book of Prognostics, Number Two:

> He should observe in acute diseases: first, the countenance of the patient, if it be like those of persons in health, and more so, if like itself, for this is the best of all; whereas the most opposite to it is the worst, such as the following: a sharp nose, hollow eyes, collapsed temples; the ears cold, contracted, and their lobes turned out; the

skin about the forehead being rough, distended, and parched; the color of the whole face being green, black, livid, or lead-colored.

As can be seen, there was no effort to separate medicine from surgery. The two developed as a single entity. In this development, one sees inductive reasoning beginning to play a more important part. It is natural that the beginning science of medicine could not escape the effect of contemporary Greek philosophy. Systems of medicine began to develop, and, since the experimental method had not been clearly defined, it was unfortunately difficult to refute some of these systems if they were established on what seemed to be firm, logical grounds. Such was the case with the doctrine of the humors—blood, mucus, yellow bile, and black bile. When the body possessed a proper balance of these humors, there was health. Where there was imbalance, there was sickness. From this a therapy of opposites could develop to counteract such an overbalance; heat, cold, moisture, and dryness were related to these humors and used in such treatment. In its detail this is a false system, and its pursual retarded the development of medicine. In principle its concept is sound, for who today would deny that an imbalance of certain humoral substances that normally exist in the body is not responsible for much disease?

After the time of Hippocrates there is not much of importance in Greek surgery. Aristotle stimulated considerable interest in anatomy, and it is possible that the Socratic attitude toward the dead human body, well expressed in the *Phaedo,* paved the way for human dissection that was soon to appear in Alexandria.

Alexander founded this town on the Mediterranean after his conquest of Egypt and named it for himself. A year or so later he died and, in the division of the empire, one of his generals, Ptolemy Soter, who may have been the half brother of Alexander, became the ruler of Egypt. Although a Macedonian, or perhaps for that reason, Ptolemy had a great intellectual respect for Greek culture and, therefore, at once began the transfer of Greek scholars and Greek books to Alexandria. This was continued by his successors until the library at Alexandria had become a fabulous institution. It contained an estimated 700,000 papyrus rolls, many of them duplicates, it is true. Scholars of the entire world centered here, and from here probably emanated the first editions of Homer, of Hippocrates, of Aristotle, and many others. Actually, this was not just a library in the sense of a repository of books; it was an institution for scholarly study of all sorts. It prospered for many years. It was in its glory for as many years, in fact, as the Ptolemys were the real rulers of Egypt. Here were fused all of the cultures of the past with those that were then present. We can see even traces of the early Egyptian influence. When this library was destroyed by invading armies of Julius Caesar, of Theodosius, and of Caliph Omar, civilization suffered an injury from which it never recovered. Some of the achievements in medicine have been preserved for us by the writings of Celsus, Galen, and Oribasius—but not enough.

Two outstanding scholars were contemporaries, Herophilus and Erasistratus, active around 300 B.C. They began to dissect the human body, and here the study of anatomy had its formal beginning. A number of the names that Herophilus gave to organs still persist—the duodenum, the retina, the dura and pia mater, the prostate, the epididymis, and many others. Unfortunately, there was no great artist such as Leonardo or Kalkar to illustrate these dissections, or if there was, the drawings were lost. It is difficult to perpetuate anatomic studies without the art of illustration, and thus much that was fundamental in anatomic knowledge was not preserved.

Studies were made of normal body functions. The pulse was counted, and the flow of blood through arteries and veins noted. The crystalline lens was removed for the treatment of cataract. Abscess of the liver was operated upon, and the effect of the emotions on the body studied to a high degree. The description of motor and sensory nerves suggested observations on the living. Not only was the human cadaver dissected, but Celsus writes that human vivisection was done on condemned criminals and describes in detail the advantages derived from such a procedure over that of the dissection of the dead body. He also criticizes the practice of such human

vivisection from an ethical standpoint in that but little could be observed that had not already been seen in the badly injured.

ROMAN MEDICINE

Celsus, a well-born Roman, was the author of many scientific works including a detailed summary of medicine. He was not a physician in the sense that he was not a practitioner of medicine. He should be considered primarily a compiler. While he thus contributed nothing new, his style was so clear and succinct that he was widely read by physicians of his period and might be thought of, therefore, as one of the important early medical educators. He was given the title "The Medical Cicero." He held the position of secretary to the Emperor Tiberius and, being an eminent scholar, was able to introduce to the Latin world a description of the best in Alexandrian surgery. Strangely enough, soon after the time of Pliny, his works were rarely referred to, and the *De Re Medicina* manuscript rested undisturbed in the Vatican until it was published in 1478 as one of the earliest of printed books. It is here that we find mandrake and poppy considered in detail as anesthetics, and it is here also that we find described the cardinal signs of inflammation, calor, rubor, tumor, and dolor.

The Romans possessed a strong antipathy to the medicine of a foreign people. For centuries the Hippocratic contributions and the medicine of the Alexandrian school were held in contempt. This is seen clearly in the speeches of Cato and the writings of Pliny. In its place the Romans preferred to adhere to incantations and mysticisms and, as Pliny has stated, were without physicians for 600 years. After the conquests by Pompey and Lucullus, in the first century B.C., many Greeks began to migrate to Rome, and it was not long before their medicine came with them. One of the first physicians in Rome was Aesclepiades, around 90 B.C. He was not the most learned nor the most able, but a beginning was made.

Shortly after the time of Celsus, when Roman medicine was reaching a period of chaos in keeping with the decline in morals and the general social structure of that once powerful empire, there came upon the scene a man whose work was destined to color the development of medicine for almost the next 1,500 years, Claudius Galen (*cir.* 130–200 A.D.). An unusually able clinician, he attracted patients from all parts of the world, among them the Emperor Marcus Aurelius, who considered him the only physician in Rome. His success was no accident. Born in Pergamon in Asia Minor, he first studied medicine at the local Aesculapion and later in Smyrna. By the age of 21, Galen was considered a well-educated physician and already was the author of several textbooks. He was not satisfied with his education, however, and for more than nine years he studied—in Corinth, Phoenecia, Palestine, Crete, and finally in Alexandria. He returned home for a while but at the age of 32 was in practice in Rome. Although a busy practitioner from the beginning, he fought the medical quackery that existed around him with all his power. He brought back decency into the practice of medicine. His ethics approached those of Hippocrates, and his teachings combined the best in pre-Hippocratic and Hippocratic medicine with the most advanced findings from the Alexandrian school. He was not content with this and continued his anatomic and physiologic studies during his active life. Since human dissection had become unpopular, he procured animals—animals of every type, even an elephant and a hippopotamus. His findings were carefully described, and his clinical and experimental writings filled many books. Well over 100 of these books have survived.

The authority of Galen in medicine was so great that none could challenge it successfully for many centuries after his death. This was not because of Galen's perfection but stemmed rather from the astigmatic concepts of clerical scholars that followed him. Although aggressive and self-confident, Galen was never blind to a new observation, and perhaps he himself would have been the first to criticize those later followers who preferred to study his writings rather than to observe natural phenomena.

MEDIEVAL MEDICINE

The Roman world was in an upheaval following the time of Galen, and the social and

cultural turmoil that existed was reflected in more ways than in surgical stagnation. Nevertheless, surgery was a casualty. Thus we find the next 1,000 years less productive. With the exception of an occasional minor introduction that may or may not have been successful, the medical and surgical world followed the principles elaborated by Galen. An example of the type of progress is furnished in the treatise on aneurysms by Antyllus as given by Oribasius. Galen described aneurysms and also recommended the ligature of arteries. Antyllus developed the concept further by recommending the treatment of peripheral aneurysms by ligating both proximal and distal to the swelling without excising the sac.

The Christian Church began to take a firm hold in the Mediterranean area, and the concept of cure of disease by prayer, incantation, and miracle began to hold sway. Disease was caused by sin. Therapy was thus related to the soul and not to the body. Not only was there an edict against anatomic dissection of the human body, but any form of surgery relating to the making of an incision was condemned. The human body could not be mutilated in any way, and a surgical incision was considered mutilation. Strangely enough, this did not apply to phlebotomy. Under such a situation, surgery could not develop. In fact, it rapidly declined in the Christian lands. All medicine, fortunately, did not suffer a similar fate, as can be seen when Benedict Nursia established a monastery, Monte Cassino (*cir.* 529 A.D.), where the care of the sick was one of its functions and where there was an herb garden. As time went on, other such monasteries were to be established to do likewise, and we thus see hospitals beginning to take more definite form. Care of the ill was becoming a function of the Church. Scientific observations and inductive reasoning gave way to kindness, compassion, and herbs. The loss, therefore, was not complete. Furthermore, in these same monasteries, the writings of Hippocrates and Galen were being preserved and laboriously copied.

In the Arab world, surgery was running into similar difficulty. Here again there was a religious ban on dissection of the human body, but it is doubtful if there existed, as some have claimed, specific statements in the Koran barring an incision of the sort made with a knife. Perhaps the considerable development of the cautery under Arab influence played a part. At any rate, much of Arab medicine and surgery resembles that of the Greco-Roman school and was undoubtedly affected by Nestorius and his followers, who had been banished from Jerusalem in 431 A.D. and who aided in the founding of a school at Jundishapur. Two figures stand out pre-eminently in the Arab world, Rhazes (860–932 A.D.) and Avicenna (980–1037 A.D.). Rhazes certainly used the knife, and one whole book in his *Continens* is devoted to surgery. Here he describes, perhaps for the first time, the use of catgut as a ligature and a suture. It was similar to that used for harp strings (kit gut), being made from the submucosa of sheep intestine and not from that of the cat. Much of the surgery followed closely that of Paul of Aegina, who lived in the seventh century in Byzantium and who followed Galen closely.

Avicenna was not a surgeon and probably never even practiced medicine. Yet his writings have been considered as representative of Arabian surgery. The writings of both Rhazes and Avicenna were voluminous and were to affect medicine of the Western World long after other forms of Arab culture had begun to wane. Perhaps the greatest surgical writer of the Arabian school in the West was Albucasis (936–1013 A.D.) of Cordova, but it is difficult to find in any of the Arabian writings any new fundamental principles. On the other hand, these authors were past masters of the aphorism. Furthermore, many of these books were obviously to a large extent compiled, the author of the compilation receiving credit that belonged to previous men. The eminent medievalist, Loren McKinney, has expressed it well:

> Greco-Arab work translated into Latin shortly before 1100 by a monk called Constantine, the African, who probably lived at Salerno for a while but who wrote and died at the monastery of Monte Cassino. For example, the earliest Salernitan surgical work often referred to as "the first modern textbook on surgery," comprised in large measure (about one half) material copied from Book IX of Constantine's *Pantegni* which

in turn had been translated from Book XIX of the *Kitab al Maliki* of Ali ibm Abbas, a tenth century Persian who in turn had borrowed it from Book VI of the *Epitome* of the seventh century Byzantine Greek, Paul of Aegina, who indicated in the prologue of his work that he had appropriated the cream of what others had written, specifically that written by the fourth century Greek, Oribasius, who in turn had drawn so heavily on Galen's work that often he is called the "ape of Galen."

As one can see, the technic of the writing of a textbook of surgery has an ancient history.

It is of interest that Jewish medicine and Jewish physicians achieved considerable prominence in the Arab world. One of these was Moses Maimonides who died in 1204 A.D., mourned by Moslem and Jew alike. As a matter of fact, the Jewish physicians seem to have fared much better among the Moslems than with the Christians, although many of them were employed as court physicians in central Europe by Christian rulers.

The period now appears in which we begin to see for the first time (if one excludes itinerant quacks) a separation of medicine from surgery. Pharmacy was being developed to a high degree and herbal medication was being exploited. In this perhaps Avicenna played a prominent part. There was another event, however, that although at the time it seemed simple and unrelated, was to play an important role in the future of surgery. In 1092 a Papal decree was sent to all monasteries forbidding monks and priests to wear beards. To fulfill this decree required the presence of a barber in monasteries, and, since it had already become the custom in many monasteries for monks to be bled at particular intervals, it was only natural that the same man be required to perform both functions; and so was wed the barber to the surgeon, the Rasor et Minutor—a simple story, probably too simple to be completely true. At any rate, this barber-surgeon was soon performing minor surgical procedures about the monastery and in secular life as well. A union had taken place that was to affect surgical education and practice more profoundly and more adversely than governments or the Church.

Important to surgical development was the attitude of the Church toward the practice of medicine, in particular surgery, by ecclesiastics. Coulton has called attention to the statement at the Councils of Reims (1125) and Lateran (1139) that "men vowed to religion should not touch those things which cannot honorably be mentioned in speech" and the enunciation of the Council of Tours (1163) that "the Church abhorreth bloodshed." While none of these directives prevented the practice of surgery by those who were not ecclesiastics, it so happened that at this period the majority of institutions at which an education could be obtained were operated by the Church. Medicine must necessarily, therefore, become involved in scholasticism that was sterile and unrewarding. Surgery must be practiced by uneducated and too often unethical craftsmen—the barber, the lithotomist, and the herniotomist.

Hope appeared on the horizon. At about this time, there developed at Salerno, just south of Naples and adjacent, the monastery at Monte Cassino, a group that was to have a considerable impact on surgery and eventually to influence university teaching profoundly. There have been questions raised as to whether Salerno was a school in the formal sense, for many who studied there possessed some deficit in the classical knowledge of the period. It was also secular. These two things could easily color contemporary opinion, and this must be remembered when appraising the criticism of Salerno emanating from universities such as that of Paris. There certainly was a definite curriculum. To be admitted, the student must be at least 21 years of age and of proven legitimacy. He must have studied logic for at least three years. The medical curriculum lasted five years with an additional year of preceptorship in practice with an older physician. This was followed by final examinations. There is something modern about all of this, including the decree of Emperor Frederick II that anyone practicing medicine must be examined in public by the teachers at Salerno "in order that the king's subjects should not incur danger through the inexperience of their physicians." This may have been the first place in which medical degrees were formally granted. Here,

also, we find the physician referred to as "doctor" for the first time. Women supposedly taught on the faculty, perhaps the most famous being Trotula, although this has been denied. There apparently was no religious, racial, or national influence to direct the faculty. Here appears academic freedom for the first time. Perhaps the best known of the Salernitan surgeons was Roger, who wrote his famous *Chirurgia* in 1080. Other well-known surgeons who at times attended this school were Roland of Parma (1170–1264) and Hugh of Lucca (d. 1257).

It is difficult to be confident about Salerno. Separating myth from fact at this late date is impossible. Much has been written about the place that is contradictory. It certainly did not resemble too closely some of the later universities of western Europe. This area did serve as a surgical center and played a part in the subsequent development of surgery in some of the other Italian centers. One can even see surgery emerging as a separate discipline. There was preserved a mixture of the Greek and the Arabic surgery; from this nucleus there was to grow a better medicine. Salerno as a school was eventually abolished by Napoleon.

Medical education began to spread northward as other universities became prominent —Montpellier, Bologna, and Padua. Bologna particularly attracts surgical attention. Strong in its faculty of law, it fought and won from the clergy its right of self-government. While there naturally was a school of theology, the attraction of the medical school was great. Here were drawn the young men who had no interest in the sterile jargon of the scholastics and who did not wish to approach medicine as clerics. Many of these students were intellectual rebels seeking an explanation for the natural phenomena they observed.

Outstanding was Hugh of Lucca who, as has been mentioned above, obtained some of his education at Salerno, and his son Theodoric (1205–1298). Among other things, they recognized the possibility and the value of primary healing of wounds. They demonstrated that the previous teachings of Roger and Roland that suppuration and "laudable" pus should be formed in wounds was both unnecessary and dangerous. Anesthetic agents also held their attention. Sponges soaked in opium, mandrake, and similar substances were used to deaden pain.

Another great teacher was William of Saliceto (1210–1277), who brought back into prominence the use of the sharp scalpel and who argued for the unity of medicine and surgery. He had two great pupils, Guido Lanfranchi (d. 1315) and Henri de Mondeville (1260–1320). Lanfranchi was banished from Milan because of political reasons and went to Lyons and later to Paris. While less enthusiastic for the scalpel than was his teacher, he carried surgical education to France, struggling to make it part of the medical teaching at the University of Paris. Later Mondeville also returned to France and became the first Frenchman to write a text of surgery. He was an able surgeon, a good anatomist, and an independent thinker. He once remarked that "God did not exhaust all of his creative power in making Galen." He probably was one of the first to use anatomic illustrations in his lectures. He advocated the use of the ligature, of torsion to vessels to stop bleeding, and of the tourniquet and again championed the value of dry wounds. To him, surgery was a therapeutic arm of general medicine. Where he saw occasion to disagree with scholasticism or even with Aristotle and Galen, he did so. He detested pomposity and his wit was caustic. As a result of these qualities, he was greatly respected and equally feared—and decidedly unpopular with the Faculty of Paris. Succeeding him in surgery in Paris was Guy de Chauliac (1300–1368). To explain Guy let us digress for a moment.

During this period anatomy was beginning to make its appearance as a formal study. Post-mortem examination for legal reasons had gradually come about and along with it the permission for public dissection. Such dissections were not taken lightly, however, for the sanctity of the body was still paramount. As an example may be cited a decree issued at the University of Tübingen that "Every three years the body of a criminal shall be dissected. All who take part shall attend a mass for the subject's soul and shall afterwards attend the remains to the grave." These dissections were not attended by curiosity seekers, but were limited to professional men—physicians, scholars, and students. The

actual dissection was usually done by a helper, the professor sitting on an elevated platform describing what was found or equally often what Galen said should be found. It is obvious that such dissections were perfunctory and contributed all too little to true anatomical understanding. Under the leadership of Mundinus (*cir.* 1275–1326), who taught at Bologna and who had developed considerable civic influence, anatomy became a basic study in the medical curriculum. In the light of our present knowledge or indeed in the light of that of a couple of centuries later than Mundinus, he was not a good anatomist. He was an inaccurate observer, his terminology was a composite of several languages, and he was handicapped by poor illustrations—but he was his own prosector. This professor forgot his dignity, did his own dissections and recorded them. He opened the door to the study of anatomy through which others were to follow, a door which, in spite of many obstacles, has since never been closed. One of his pupils was Guy de Chauliac.

Guy was critical of Mondeville; and whether from jealousy or sincerity, the result was the same. It endeared him to the physicians of Paris. He scorned the early suture of wounds and the ensuing lack of suppuration. To him good wounds must be purulent. The teaching of anatomy by illustration was a subject for ridicule. In spite of all this, Guy was, for his period, a competent observer and an excellent clinician. He was forthright and dogmatic. His *Chirurgia Magna* was to dominate the surgical world until the time of Paré. Here one finds described nicely the treatment of femoral fractures by traction and the use of a rope suspended above the bed of the patient to aid the patient in changing his position. Perhaps it is not too unkind to say, however, that one sees in this book much of the teaching of one of his old professors—Henri de Mondeville.

Slowly a knowledge of surgery spread northward. Prominent in London was an English surgeon, John of Arderne (1306–1390). While most of his education was obtained in Europe, he was a "practical" man, his approach being completely unfettered by the experience of others. His great interest in fistulas led him to the recognition of cancer of the rectum and concerning it he gave the admonition, "Do not be led away and offer to operate. It will be a disgrace to you." He made the diagnosis by digital examination of the rectum. Unfortunately, John is also remembered by the exorbitant fees he charged.

This resurgence of independent thinking on the part of well-educated surgeons, in spite of the handicap of itinerants and barber-surgeons, began to make itself felt throughout Europe. In the thirteenth century a medical school had been established at the University of Paris but, since it was under clerical control, surgery could not be taught. The ban on the practice of surgery did not hold for those clerics who were not active in church affairs, and the Collège de St. Côme had been established in Paris as early as 1160; here surgery was taught. A sort of academic compromise had come about, for Latin was the language used at this school but surgery could be taught and the faculty could be married. It was to this institution that Lanfranchi came in 1295 and Mondeville later. By their time, St. Côme had achieved considerable respectability. Unfortunately, it also tended to become restrictive and its licentiates, who were called "surgeons of the long robe," found themselves at odds not only with the more sophisticated group at the University of Paris but also with the more illiterate barber-surgeons, called "surgeons of the short robe." Most of these latter surgeons knew no Latin and, since texts were not as yet written in the vernacular, had no way of studying the older classical surgery of Mondeville and Guy. This led to confusion throughout France, for there thus existed three different groups of practitioners. Eventually this was to be rectified, but not until after a long struggle.

Although admitting a prejudiced point of view, it seems to this author that the surgery of this period has never received its proper place in its effect on subsequent history. Men like Lanfranchi and Mondeville made themselves outstanding because of their independence of thought. Dogmatic scholasticism found itself competing with virile minds in surgery capable of agnosticism and ready to break with the past. These men were concerned with the interpretation of phenomena, not with metaphysics. Given a printing press, they would become dangerous. It does not seem accidental that the area that nurtured

these minds, Italy, was also to give rise to many others who were to lead western Europe into the Renaissance. Active intellectual ferment does not remain confined.

Leonardo da Vinci (1452–1519) was one of these. He is not considered a surgeon; yet, as was true in many fields, this genius had surgical ideas that were sound. He is supposed to have dissected over 30 bodies, and his accuracy of observation combined with his ability as an artist gave anatomic information not since equaled. Unfortunately, these illustrations were not published until some redrawings appeared in the late eighteenth century, and surgery suffered because of this. Fortunately, excellent copies are now available. Forty years after Leonardo, Vesalius (1514–1564) was to make his great contribution.

Vesalius, a Belgian, studied at Paris under Sylvius and Guinther, the latter in particular giving him great encouragement. He subsequently went to Italy and, in 1537, was appointed professor of surgery and anatomy at Padua. Although a popular lecturer, Vesalius soon began to concentrate on anatomy. He was impressed, during his dissections, with the many errors present in Galen's anatomic concepts just as he was with the physiologic implications of some of his new findings. With another Belgian, Jan Stephan van Kalkar, who had been a pupil of Titian, as the artist, charts of his dissections were made. Six large plates of these dissections were published, his *Tabula Anatomicae*, to be followed by the well-known *De Humani Corporis Fabrica*. He was 29 when this came off the relatively new printing presses at Basel, under his careful inspection. At about the same time the *Epitome* was produced. While first at Padua, Vesalius had translated the *Ninth Book of Rhazes*. While *Fabrica* was being prepared, he participated in the translation of an edition of Galen. In describing previous concepts of this master he could, therefore, speak authoritatively and then prove his point by visual means. The authority of Galen had, at last, been successfully challenged. It remained for William Harvey to give it the final blow. But Vesalius had now become a controversial figure. With the praise for him, there was also bitterness and jealousy toward him. He resigned his chair at Padua to become the physician of Charles V of Spain and, later, of this king's son, Phillip II. Even his success as a clinician in Madrid and as a surgeon in the army aroused envy and intrigue. He also found himself in a country where "not even a skull could be had" for anatomic purposes. He died on a return journey from Jerusalem in 1564, when his ship was wrecked.

Succeeding Vesalius at Padua was Colombo (1510–1599), later Fallopius (1523–1562), followed, in turn, by Fabricius ab Aquapendente (1533–1619), the teacher of William Harvey. In Rome was Eustachius (1520–1574). These men all made great contributions to anatomy and yet, at the same time, they taught and practiced clinical surgery. Of the great anatomists of this period only Michael Servetus (1509–1553), who demonstrated the pulmonary circulation, was not a practitioner of surgery. Knowledge of anatomy was no longer a philosophic adornment, but had become a part of the surgeon's armamentarium. Unfortunately, the ordinary surgeon was not ready to use this knowledge completely. In most respects, clinical surgery had been making slow progress. Although Paracelsus (1493–1541) had made a valiant effort to reintroduce the concept of a clean wound, he had had little success. Paracelsus was not a surgeon. The lithotomists and the herniotomists were ubiquitous, although insofar as the growth of surgery was concerned they were more of a nuisance than a hindrance.

A new development in the progress of mankind made its appearance which also affected surgery: Gunpowder was invented. Wars thus became more frequent and, as has been stated, wars always contribute greatly to surgical knowledge. Wounds were more severe and also more common. Much could be learned; and, during wars, surgeons are important to kings. Surgery was ready once again for dominant leadership.

Leadership appeared in the form of a barber's apprentice, himself a barber-surgeon—Ambroïse Paré (1510–1590). Following his apprenticeship, he went to Paris where he lived for three years in Hôtel Dieu, observing and studying the critically ill. After this, he sought and obtained army service and for the next 30 years engaged in one campaign after another, in the interims residing in Paris. His

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THE RENAISSANCE

The most important thing taking place during this period, however, was outside of surgery and was to affect it only indirectly at first. That phase of intellectual resurgence known as the Renaissance was gathering momentum. During the year that *De Fabrica* was published, Copernicus presented his revolutionary treatise on astronomy. Soon philosophy was to be given its first rigorous reorganization in centuries by Francis Bacon and by Descartes. The microscope was being perfected, and the giants Galileo and Newton appeared on the scene. In a few brief years, experimental science with objective measurement of phenomena had come about. Many of these men had studied medicine; all were scientists.

In Padua, Fabricius ab Aquapendente, one of the successors to Vesalius in the chair of anatomy and surgery, had as a student William Harvey (1578–1657). Apparently Harvey was impressed with the demonstration by Fabricius of valves in veins and attached to them a function not appreciated by his teacher. This led, following his return to England, to a series of carefully conceived experiments that demonstrated effectively the circulation of the blood. His book, *De Motu Cordis et Sanguinis*, published in 1628, in many respects became one of the most important publications in medicine of all time. Not only did it destroy the last vestige of Galenic beliefs, but it also gave the concept of the body as a dynamic organism in a way not hitherto conceived. Here was the real demonstration of the value of experimentation in medicine. To observation and reflection could now be added experimentation. Medicine became a science in the true sense, and from this time on not only could experience continue to be cumulative but proven fact began to pile on proven fact. The result was indeed revolutionary.

In Italy, Malpighi (1624–1694) demonstrated with an improvised microscope the capillaries and capillary circulation, the layers of the skin, the lymphoid nodules of the

spleen, nerve pathways from the spinal cord to the brain, and the glomeruli of the kidneys. Van Leeuwenhoek (1632–1723), with a better instrument, showed that blood contained a solid component, red cells. He demonstrated striations in muscle and the presence in the scrapings from teeth of "little animals, more numerous than all the people in the Netherlands, and moving about in the most delightful manner." Robert Boyle (1627–1691) and Robert Hooke (1653–1703), his assistant, proved that air was necessary for an animal to sustain life, as well as for combustion, and that the lungs served to provide this function. To Hooke, we are also indebted for the concept of the cell; and, although his ideas in the light of present knowledge were primitive, here we find for the first time the use of the word "cell." The Royal Society was established, and experimentation was the order of the day.

BARBER-SURGEONS

These men and others like them were not clinical surgeons but their careers were to affect surgery deeply. It is impressive, however, how long this was to take. Quackery was rampant. The barbers, untaught and uncontrolled, practiced shaving, haircutting, bleeding, or any type of surgery they wished. Itinerant herniotomists, cataract extractors, and lithotomists roamed from city to city. In Italy, the problem was not so great. As we have seen, there were universities in which a surgeon could obtain a good education, and there were moderately effective laws of licensure. By the mid-seventeenth century the schools at Leiden and Amsterdam began to obtain prominence as centers where anatomy and surgery were being taught well. In France, following Paré, the barbers had been amalgamated with the surgeons and, with the triumph of the physicians, the Collège de St. Côme lost greatly in prestige. Germany was showing progress, but Spain remained in the doldrums.

In England in 1462, during the reign of Edward IV, a Barber Surgeons Corporation had been granted a charter which, while elevating the status of the barber-surgeon, was designed to exclude from practice the itinerant, irresponsible practitioner. This was not too effective; and, during the reign of Henry VIII, Thomas Vicary (1495–1562), who was surgeon to the king and a member of the Barber Surgeons Corporation, succeeded in obtaining a royal decree calling for more stringent rules governing the practice of surgery and the privilege of obtaining bodies for anatomical dissection. The barbers were no longer allowed to bleed patients or to do surgery of any kind; in return, the surgeons were no longer allowed to shave people or to cut their hair. However, educational facilities for the surgeon remained of a low quality. This arrangement was to persist in England until 1745 when, particularly as a result of the activities of Cheselden, by an act of Parliament, there was a complete separation of the surgeons from the barbers. Finally in 1800 a charter for the Royal College of Surgeons was issued by George III.

The early eighteenth century saw the popularity of the French schools increasing. Students came from all parts of Europe, not because of the presence of outstanding teachers so much as because the growing facilities for surgical study in Paris exceeded those found elsewhere. There were three schools in Paris where a medical education could be obtained. While the physicians had won a victory over the surgeons some years earlier in Paris, better recognition of surgery soon appeared, due in part to the support of Louis XIV and Louis XV.

Toward the end of the seventeenth century, the surgeon Felix, with great fanfare, had performed successfully an operation for anal fistula on Louis XIV. This led to considerable royal interest in surgery and its state in France at that time. So important was this that one should not be too critical of the way this interest was aroused. Felix was followed by Mareschal (1658–1736), who was not only surgeon to Louis XIV and Louis XV but also surgeon of the Charité Hôpital. His influence on the king was great, and he was largely instrumental in having Louis XV establish several chairs of surgery at St. Côme, greatly to the discomfiture of the Faculty of Medicine at the University of Paris. At this period, de la Peyronie (1678–1747) played an impressive role. A native of Montpellier but educated in Paris, he had one of the most successful surgical practices. He gave generously of his time and money for the better-

ment of surgery, and it was largely through his efforts and the work of Mareschal that the Academy of Surgery was established in Paris in 1731. Not content, he succeeded in having an ordinance passed in 1743 that definitely separated the barbers from the surgeons in France and placed surgery in a position of professional dignity. Today de la Peyronie is best remembered as having described a type of painless fibroplasia of the penis.

THE BEGINNING OF MODERN SURGERY

Other outstanding surgeons of the period were Jean Louis Petit (1674–1750), noted for his improvements in the technic of circular amputation, the invention of the screw tourniquet, his operation for hernia, and his studies on the clotting of blood. Although not the first to do so, he is supposed to have performed cholecystotomy. There was Dionis (d. 1718), who was a popular teacher of anatomy and left an excellent account of Frère Jacques, the noted wandering lithotomist. Littré (1658–1726) is well remembered for his work on hernia and as an anatomist. He proposed the operation of colostomy in 1710. This was apparently first performed successfully, however, in 1776 by Pillore, a surgeon in Rouen. Toward the latter part of the century, Desault (1744–1795) was the outstanding teacher in France. His lectures in surgical anatomy were unique and practical. He applied this information to the treatment of fractures and to the improvement of surgical technic to such an extent that students came in crowds to hear him. The sisters in Hôtel Dieu registered a formal complaint because the 200 to 300 strangers, besides the regular students at the hospital, who came to hear his lectures constituted a deterrent to the dressing of wounds and the education of their own students. A colleague of Desault who published a monograph on surgical operations with him was François Chopart (1743–1795), remembered today for the amputation technic that bears his name.

In Germany, surgery had been slow in getting started, owing to the social conditions in this land at the time and to the dearth of educational facilities. One of the early German surgeons who had done much to elevate the standard of practice was Wilhelm Fabry (1560–1634), known also as Fabricius Hildanus. After obtaining an excellent classical education, he spent a number of years acquiring surgical experience in many centers. His writings exhibit sound judgment for the period and prove him to have been an aggressive and able man. Among his other achievements, he apparently was the first to perform a cholecystotomy for the removal of gallstones and have the patient survive, no mean feat in 1618. Following Fabry was Johann Schultes (1595–1645), remembered today chiefly by virtue of an ingenious bandage that he devised—the Scultetus binder. Similar ingenuity was evidenced in the numerous surgical instruments he invented, many of them prototypes of the ones used today.

Dominating the field of German surgery in the eighteenth century was Lorenz Heister (1683–1758), who received most of his education in Holland. He found, upon his return to Germany, that his lectures in Latin were completely unintelligible because few of his students had studied Latin. He was forced, therefore, to change to the German language in his lectures and writings, and, probably as a result of this, his influence immediately was felt throughout western Europe. His book *Chirurgie* (published in 1718) was translated into Latin. Later, the Latin edition was translated into English, and in some centers in England was the standard text in surgery for almost a century. Heister made no dramatic contributions to surgery and is best known today for his demonstration of the small valves in the cystic duct. His writings were simple, sound, and voluminous. In originality of thinking and of work, he was not of the caliber of a contemporary colleague, Albrecht von Haller (1708–1777), who taught at Göttingen. Although he was professor of anatomy and surgery, it is highly probable that von Haller never operated on a single patient. His fields of interest were broad and one encounters his contributions at almost every turn—whether it be inconsequential, as on the vagaries in the occurrence of the right colic artery, or substantial, as on the descent of the testes, which he proved by beautiful anatomic dissections of the fetus. It was this work that led both Pott and the Hunters in England to explain the mechanism of indirect inguinal hernia on the basis of persistence of

the peritoneal sac, an explanation which led to a most vituperative argument over priority that has been reported by Beckman. Each claimed to have originated the concept; neither gave von Haller much credit. Of particular interest is the use of the experimental method by von Haller. Also, because so many students from all over Europe came to study under him, his importance in the development of surgery as a science cannot be overestimated. A successor at Göttingen, August Richter (1742–1812), as well as being a particularly able clinical surgeon, did much to advance the Haller concept of scientific surgery. While one can see the beginning of the tremendous surge forward that surgery was soon to take in Germany in the works of these men, he also notes the conversion of the Friedrich Wilhelm Institute into a medical school for the education of military physicians and surgeons.

In Leiden and Amsterdam during the eighteenth century both medicine and surgery remained at a high level. Outstanding in surgery were Ruysch (1638–1731) and Rau (1668–1719) at Amsterdam and Camper (1722–1789) at Leiden. The great Boerhaave, in internal medicine, was such an imposing figure at this time that perhaps one hears less of the surgery than would ordinarily have been the case.

During this period we can give but little space to the detailed advances being made in surgery, for there is much repetition. Because of frequent wars great attention was given to wounds and fractures, particularly of the extremities; and, with the advent of the dissemination of anatomic knowledge, treatment had been markedly improved. Amputation technics had been perfected and, with more confidence in the ligature, aneurysms were being approached surgically, especially those in the extremity. Injury to the skull, the brain, the spine, and the peripheral nerves and, on rare occasions, even to the abdominal viscera and the chest were now being treated aggressively. The classical fields of the charlatans—hernia, bladder stone, and cataracts—had been taken over and therapy improved. Now, before surgery could expand further, even before it could expect to be perfected better, it was necessary to learn more about the underlying nature of the disease process, and the clinical picture that it produced.

Giovanni Battista Morgagni (1682–1771) at the age of 79 published his monumental *De sedibus et causis morborum per anatomen indagatis*. Symptoms were correlated with the disease process found in particular organs at autopsy; it was not a casual correlation. The most critical scrutiny was exercised by Morgagni, and in his proof he was most demanding. To him, the organ was the basic unit in pathology. While this was to prove too rigid a concept, here was something tangible toward which therapy, both medical and surgical, could be directed. His experience was rich, and there appear to be few diseases that did not come under his scrutiny. In his ultimate effect on medicine Morgagni stands alongside Harvey in the importance of his contributions. From the surgical standpoint this concept of morbid anatomy was to be pursued a bit later in England by John Hunter.

Although Henry VIII had removed the English hospitals from the control of the Church and made them secular institutions, active teaching in these hospitals did not occur until a much later date. In the seventeenth century, anatomic and, later, surgical teaching began in the London hospitals. In 1763, the first surgical lectures were given at the St. Bartholomew's Hospital by Pott (1714–1788) and at St. Thomas' by Cheselden (1688–1752) in 1720. Later, when the medical school began at Guys it united with that at St. Thomas', surgery being taught at the latter and medicine the former. These two men, Cheselden and Pott, did much for British surgery. As we have mentioned earlier, Cheselden exerted great efforts toward obtaining separation from the barbers, and perhaps more credit is due him than to any other surgeon for establishing an educational and intellectual climate in England that would attract good minds to surgery. The clinical acumen of Pott is preserved by the unusually lucid description of several diseases which bear his name. His influence was considerable and he used it for the good of surgery. He wrote with great clarity and apparently his lectures had the same quality. John Hunter (1728–1793) studied under both of these men.

Hunter came down from Scotland to be with his brother William, who was some ten years his senior. William had obtained a good classical education after which he studied medicine. He was a cultured, urbane teacher and was highly respected; his younger brother apparently possessed none of these qualities. John did have, however, intense curiosity, a logical mind, the capacity to work, and considerable self-assurance. While it is true the historical moment in which he lived played a considerable part also, these attributes led to one of the most imposing careers in the history of surgery. And yet there were few single great discoveries, and there is evidence of plagiarism unless one assumes that he rarely read—which is true. For example, we have mentioned the episode of testicular descent and inguinal hernia. Another is the implantation of lead pellets into the shaft of long bones of pups to demonstrate that longitudinal growth took place at the epiphyses. This had been done with chicks a century earlier by Stephen Hale. It was a pretty experiment, though, reminiscent of William Harvey, and its inception represented only one of Hunter's many contributions to the study of bone growth. He was deeply fascinated by midgets and giants, and the story of his acquisition of the skeleton of the Cardiff giant is legendary. He was a great collector of biologic material, his museum comprising not only pathologic specimens, but all varieties of animal life as well. His interest in comparative anatomy was phenomenal. He was in the army from 1761 to 1763, and used much of this experience in his treatise *Blood, Inflammation and Gunshot Wounds*. Some of this early experience was later subjected to animal experimentation. The demonstration of the increase in collateral circulation following ligation of a main artery will serve as an example. Certainly, following his day, surgical teaching could be limited no longer to a knowledge of anatomy. Physiology and pathology were brought into surgery, and experimentation became an essential feature. Much has been written about Hunter—so much that few surgeons are so resistant to history as to have escaped reading about his life; therefore further details may be omitted here.

If a good teacher is known by the careers of his students, Hunter was a good teacher. Outstanding among these students was John Abernethy (1764–1831), who succeeded Pott at St. Bartholomew's. He gave private lectures on anatomy in his home. These became so popular that a lecture room was built for him at St. Bartholomew's. Abernethy maintained the interest of his teacher in arteries and, in 1796, performed the first successful ligation of the external iliac for aneurysm. In 1798, he ligated the common carotid for hemorrhage, again successfully. He demonstrated the regeneration of peripheral nerves following neurectomy and suture. Perhaps his greatest success, however, was as a lecturer, for he had a large following. Other outstanding pupils of Hunter were Henry Cline (1750–1827), surgeon to St. Thomas' Hospital; William Blizard (1743–1835), who founded the medical school at the London Hospital; and Astley Cooper (1768–1841). Like the rest of the men who worked under Hunter, Cooper was interested in aneurysms, ligating the common carotid artery for this lesion in 1805 and the abdominal aorta in 1817. Today he is best remembered for work on the breast.

Edinburgh was also becoming an important surgical center at this time. Alexander Pitcairn, who had studied at Leiden, returned to his home in Edinburgh in 1694 and, after much travail, succeeded in starting a medical school there. There was difficulty in obtaining cadavers for dissection, but, with the help of the surgeon Monteith, permission was obtained for an occasional body for dissection. At this time there was no connection between this school and the University of Edinburgh. In 1719, Alexander Monro (1697–1767), who had studied under Cheselden and Boerhaave, returned to Edinburgh and through the good offices of his father, John Monro, a retired army surgeon, became demonstrator in anatomy to the Surgeon Company. Monro immediately impressed his fellow townsmen with his ability—which was real. Unfortunately, because of gnawing fear of the menace of grave-robbing in order to obtain cadavers, there were many people in the area who looked upon his dissecting room with suspicion. This feeling grew so intense that Monro had his anatomical specimens moved to the University in 1725, to prevent them from being destroyed. From then on, he gave

his lectures at the University of Edinburgh, although it was later that the School of Medicine was started at the University. The venture in Edinburgh was successful, it seems, primarily because the teachers were able. Alexander Monro is a good example. His original contributions to anatomy and surgery were minor, yet his lectures and anatomic demonstrations were excellent.

He was succeeded by his son, Alexander Monro II (1733–1817), who performed even more impressively. He studied anatomy under both William Hunter and Meckel; he described the foramen between the lateral ventricles and the third ventricle. It was also he who recommended thoracentesis. Although consulted by surgeons, he himself did not operate. He had much to do with the growth of Edinburgh as a medical center. Unfortunately, his son Alexander Monro III (1773–1859), who succeeded him, was a less effective person. Nevertheless, he had tenure and thus remained in the chair of anatomy at Edinburgh for 38 years, making a total of 126 years in which a single family controlled a particular professorship. In the beginning at Edinburgh, the professor of anatomy also taught surgery, but in a desultory way. Most of the surgery was performed by general practitioners.

In spite of the place occupied by surgery in the curriculum, Edinburgh was the home of several outstanding surgeons. One of the best known was Benjamin Bell (1749–1806), who was surgeon to the Royal Infirmary and the author of one of the important texts of surgery of the period. John Bell (1765–1820), no relation to Benjamin, was also prominent. John Bell was excluded from a position in the Royal Infirmary as a result of local political maneuvers. Nevertheless, he had one of the largest surgical practices in Edinburgh and, in spite of great difficulties, developed a real reputation as a teacher. He had a younger brother, Charles Bell (1774–1842), who at first assisted him in his anatomic demonstrations. In order to escape much of the bitterness existing in medical circles in Edinburgh, Charles went to London where he eventually was appointed Professor of Anatomy and Surgery at the Royal College of Surgeons of England. He previously had obtained the Windmill Street School of Anatomy formerly owned by the Hunters, had seen service as an army surgeon, and had become associated with the Middlesex Hospital. Charles Bell was an excellent artist and was able to depict his observations in a striking manner. Among other discoveries he demonstrated the difference between motor and sensory nerve filaments and described the particular function of the anterior and posterior spinal nerve roots. Today the student meets him through the respiratory nerve of Bell, which supplies the serratus magnus muscle, and through Bell's palsy, a paralysis of facial muscles supplied by the seventh cranial nerve. Bell's book, *The Nervous System of the Human Body,* was the first real textbook of human neurology. In 1835, the chair of surgery at the University of Edinburgh became vacant and was offered to Bell. He went back to his home at the age of 62 with the remark that while London was a good place to live in, it was not a good place in which to die; he died only a few years later. Mankind is definitely richer because Charles Bell lived—a noble spirit indeed.

Surgery as such hardly existed in America until after the Revolution. Men with special, formal education in surgery were few, for such an education must necessarily have been obtained abroad. Since there were not many who could speak French, most of those who went abroad went to London or Edinburgh. Supposedly the first native American to receive such an education was John Moultrie of South Carolina, who graduated at Edinburgh in 1749. The first medical school in America was started in Philadelphia in 1761; William Shippen, the first professor of surgery, had studied with the Hunters in London and at Edinburgh. In New York, Samuel Bard, who also studied in Edinburgh, succeeded in persuading the trustees of Kings College, later to become Columbia University, to establish a school of medicine in 1768. In Boston, John Warren (1753–1815), also a surgeon, played an important part in the founding of the Harvard Medical School in 1783.

Surgery in America was saved the turmoil of being involved with barbers, the restrictions of ecclesiastical control, and the internecine warfare with physicians. This is, to a great extent, the result of the historic period

in which it developed, and also in part to the influence of Edinburgh, where so many early American teachers were educated. Since most surgeons in Edinburgh also practiced general medicine, the tendency to early specialization in surgery was not to take place in America until a much later date. As we have stated earlier, medicine is a part of a people's culture, and it is not surprising that few early American surgeons were scholars and that they lived around larger centers. At first, American surgery represented a transfer from European centers; later, it assumed a personality of its own. There was a paucity of good libraries of medicine, but there were courage, ingenuity, and self-reliance. Because many times isolated men did not immediately seek publicity for their performances, it has been felt that they were not cognizant of what they had done. Such was probably not entirely true.

Among the surgical figures in the early nineteenth century in America, besides those already mentioned, were: Physick (1768–1837), professor of surgery at the University of Pennsylvania, became an important surgeon for his time. McDowell (1771–1830) of Kentucky, noted chiefly for having performed the first successful ovariotomy in 1809, was also an excellent lithotomist and operated frequently for strangulated hernia. Dudley (1785–1870), professor of surgery at Transylvania, was well known for his operation for bladder stones. J. C. Warren (1778–1856), who performed the surgery when ether was first used at the Massachusetts General Hospital, was well known for his aggressive approach toward the surgery of malignant tumors. John Bard (1716–1799), in 1759, did an abdominal section for ruptured ectopic pregnancy. Deadrick (1773–1858) of Tennessee resected the lower jaw in 1810; McCreery (1783–1826) did the first total resection of the clavicle. Nathan Smith (1762–1829) was one of the leaders in medical education. He performed ovariotomy in 1821, apparently at that time being unfamiliar with the previous operation of McDowell. One of his particularly important contributions was the recognition of localized osteomyelitis in the shaft of long bones and drainage by means of a trephine. Smith founded a medical school at Dartmouth and became professor of medicine and surgery at the newly organized medical school at Yale in 1813.

One of the boldest of early American surgeons was Valentine Mott (1785–1865), a student of Astley Cooper. He held the chair of surgery at Columbia College, retaining this position when Columbia merged with the faculty of the College of Physicians and Surgeons. He was professor of surgery at the new Rutgers Medical School and later professor of surgery at the Medical Department of the University of New York. He attracted world-wide attention in 1818 when he ligated the innominate artery. According to Billings, he "tied the subclavian eight times, the primitive carotid fifty-one times, the carotid twice, the common iliac once, the external iliac six times, the internal iliac twice, the femoral fifty-seven times and the popliteal ten times." He also removed the entire clavicle, the right lower jaw, and amputated at the hip joint. His account of the construction of a wooden retractor at the operating table to displace the intestines for better exposure of the common iliac is a highly dramatic story.

While Paris also was one of the favorite centers for Americans to study, it was frequented perhaps more by those primarily interested in internal medicine. Especially were Americans impressed by the systematic methods of analysis that were being introduced, these methods subsequently being reflected in surgical practice. One of the important early contributors to this system was Bichat (1771–1802), who, while still young, died from septicemia resulting from a wound obtained while dissecting. Bichat carried the concepts of Morgagni from the disease of organs to the pathologic processes involving the tissues that composed the organs. He used neither the microscope nor illustrations, being fearful that they would distort his observations. Here one encounters the correlation of anatomy, physiology, and pathology with symptoms. With the advent of improved methods of physical diagnosis, auscultation, and percussion, the clinical picture could be more accurately described.

P. C. A. Louis (1787–1872) introduced statistical study not only to clinical findings but also to therapy; it was largely due to his efforts that bleeding was thrown into discard.

He paid great attention to a written clinical record. Such was brought to this country by Jackson and introduced at the Massachusetts General Hospital, the hospital records in use today being modified from it only in detail. The indications for surgery and the results of various therapeutic procedures could now be studied from a statistical standpoint.

During the French Revolution and the period of the Napoleonic conquests considerable change occurred in French medical education. The universities were involved in the ensuing chaos, and almost complete reorganization occurred. Military surgery for a time was stressed, one of the outstanding surgeons of this period being Larrey (1766–1842). He introduced the ambulance to transport the injured on the battlefield, considerably lowering mortality. Many of the present principles of military surgery were his contribution, and his writings concerning problems during the African campaign were useful in World War II.

In civilian surgery, Dupuytren (1778–1835) was the outstanding figure until his death. It is difficult to find much good said of this man as a person. He apparently would tolerate no rival, was ruthless in obtaining his own advancement, and was second to none in arrogance. He ruined the careers of many of his more promising students when he felt they were in his way; for example Lembert, who, as Dupuytren's assistant, brought out the principle of serosa-to-serosa healing of wounds of the intestine and devised a suture to bring such healing about. This contribution, which could make intestinal surgery possible, lay fallow for a generation as a result of the scathing attack on it by his professor. Nevertheless, Dupuytren had a tremendous following of students, and his surgical innovations and the character of his clinical care were of a high order. A perusal of his lectures, many of which have been translated into English, reveals a scholarly background, careful observations, and splendid technical proficiency. He was no ordinary surgeon, and, in all probability, he earned the professional esteem in which he was held both in his country and abroad.

There were other well-known surgeons of this period—names that are still familiar—Marjolin, Roux, Lisfranc, and Amussat among them.

SURGICAL ANESTHESIA

From the very beginnings of medicine the problem of pain had been foremost; and also from the very beginning many drugs had been used to relieve this horrible affliction. Some of these substances, such as opium, mandrake, and alcohol, have already been referred to. But these drugs were not adequate for the acute pain produced by surgical maneuvers. Amazingly enough, substances with adequate analgesic action had been available for a long time but would not be accepted by the surgical world. Sulfuric ether had been known since early times; Joseph Priestly isolated nitrous oxide in 1776. Furthermore, the fact that these substances, when inhaled, would produce a disturbance in the conscious state with degrees of analgesia had also been known for many years. Just why they had not been brought into use by the surgeon, when viewed in retrospect, is hard to understand. Raymond Lully in the thirteenth century discovered sulfuric ether in his alchemic laboratory, a white fluid to which he gave the name "white vitriol." Over two centuries later, Paracelsus mixed alcohol with sulfuric acid and condensed the vapors coming from this mixture. He tried the effect of this clear fluid on chickens. He writes: "Of all the extracts of vitriol this particular one is the most important, being stable. Furthermore, it has an agreeable taste, so that even chickens take it gladly, and thereafter fall asleep for a long time, awakening undamaged. In view of the effect of this vitriol, I think it especially noteworthy that its use may be recommended for painful illnesses, and that it will mitigate the disagreeable complications of these." In 1542, a year after Paracelsus had died, an itinerant apothecary's apprentice, Valerius Cordus, who had copied many of the prescriptions of Paracelsus when he served as assistant, sold them all to a committee of learned Nuremberg doctors. There the information on ether remained forgotten, for no one bothered to read about it. Years later, Sir Isaac Newton and Godfrey and Boyle referred to "sweet vitriol." In 1818, Michael Faraday, who had worked with gases in Sir Humphrey Davy's laboratory, wrote, "When

the vapor of ether is mixed with common air and inhaled, it produces effects very similar to those occasioned by nitrous oxide. By the incautious breathing of ether vapor, a man was thrown into a lethargic condition which, with a few interruptions, lasted for thirty hours." A few years earlier Davy had written, "As nitrous oxide in its extensive operation seems capable of destroying pain, it may probably be used with advantage during surgical operations in which no great effusion of blood takes place."

These references to early observations are made here in order to give emphasis to the absurdities of priority and to stress the importance of the proper intellectual milieu in establishing the use of this tremendous gift in the hands of surgeons; yet a bitter controversy over priority has arisen. It is true that Dr. Crawford Long removed a tumor from the neck of James Venable on March 30, 1842, under ether narcosis, although at the time it was not reported in a medical journal. It is also true that W. T. G. Morton anesthetized with ether a patient upon whom Dr. J. C. Warren operated on October 16, 1846, at the Massachusetts General Hospital. It has also been established that Morton, a dentist, had consulted Charles T. Jackson, a chemist, who had suggested the use of sulfuric ether as the anesthetic agent. And it is likewise known that Horace Wells, a Hartford dentist, had used nitrous oxide as an anesthetic agent in extracting teeth in 1844. These were all important contributions and should be so considered. There is enough glory to be divided among all these men without further rancor over priority.

There were other anesthetic agents. In 1831, independently, chloroform was synthesized by Liebig, by Saubeiran, and by an American physician, Dr. Samuel Guthrie, of upstate New York. A few months later it apparently was used by Guthrie as an anesthetic while he reduced a fractured forearm of a young boy. Its introduction as an anesthetic agent in obstetrics by Simpson in Edinburgh in 1847 was rapidly followed by use elsewhere. In 1858, John Snow, perhaps the most important of the early anesthetists, published a monograph *On Chloroform and Other Anesthetics*.

Cocaine was introduced as a local anesthetic by Anrep in 1879. Koller employed it as a topical anesthetic in ophthalmology; and William Halsted showed its great value in blocking conduction in peripheral nerves. Synthetic chemists have now produced many agents that have more or less the same physiologic actions without the danger inherent in the use of cocaine.

The introduction of surgical anesthesia produced a tremendous change in the character of the surgery that could now be performed. Besides the relief of pain, it provided the surgeon with two invaluable tools he did not previously possess—time and muscular relaxation. Procedures not hitherto possible could now be performed with ease. The next paramount need was safety.

SURGERY AND THE BIOLOGICAL SCIENCES

To achieve safety the surgeon once again profited by development in other areas of medicine. The outstanding hazard in surgery was one of wound infection and, like most important biologic problems, its solution required a considerable amount of basic information before it could be reached. Slowly this had been taking place but, with the advent of experimentation in medicine, the pace began to quicken. It is assumed that, before the advent of the antiseptic period, surgeons did not strive for a dry wound or for healing by primary intention. As we have already noted, the early closure of wounds is old, as is the removal of foreign material. It will be recalled that when the ligature came into use, it was quickly seen that the ends of the thread should be long enough to extend out of the wound so that they could be "discharged by nature." Dead space was known to be hazardous and adequate drainage was desirable. As a matter of fact, an aphorism of John Woodall in the early seventeenth century can still be used to advantage, "Packeth not thy wounds too tight." The great value of cleanliness had also been well recognized. It is true that pus was often spoken of as "laudable"—as it is true that many times it actually was. Greatly feared by all surgeons was "wound fever," the hot, red, painful wound associated with a febrile state, often accompanied by delirium. This wound often

killed. When recovery did take place it occurred in one of three ways—resolution, suppuration, or gangrene. Obviously the first was preferable, but when it did not obtain suppuration was sought for. This represented localization of the process and at such times was indeed "laudable." Suppuration was not preferred to primary healing in a clean, surgical wound, however, as has been so often inferred. A clear idea of the treatment of wounds toward the close of the eighteenth century can be easily obtained by reading Benjamin Bell's *A Treatise on the Theory and Management of Ulcers.*

But what was pus, and what was its origin? What was inflammation? These questions needed an answer. The physiologist played an important role in the beginning of their solution. Men were beginning to consider the body as an integrated group of dynamic systems; these same men also taught students who subsequently became surgeons. Two of these teachers, Johannes Müller and Magendie, described the leukocyte as it existed in the blood. Pus was noted to contain leukocytes, but it was also considered to be chiefly a lipid; therefore its significance missed. A better knowledge of cells was necessary before inflammation could be understood.

The concept of the cell as an integral part of tissue is usually attributed to Schleiden and one of Müller's students, Schwann. As we have already seen, this is not exactly true for the concept of cell structure had existed years earlier. The evolution of this knowledge is too involved to detail here. What Schleiden and Schwann did do, however, was to insist that all tissues were composed of cells. They also sparked a controversy leading to Müller's demonstration that malignant tumors were composed of cells and Virchow's contention that the cells served as the basis of all pathologic processes and that all cells were derived from previously existing cells. This view of cellular pathology, to the exclusion of all other processes, has been subject to some modification with the resurgence of the importance of the humoral mechanisms of disease, but perhaps not so much as appears on the surface. The contributions of Virchow, Rokitansky, Cruveilhier, Weigert, Conheim, and others in describing the cellular and vascular processes involved in inflammation developed rapidly and were of the utmost importance to the surgeon.

Sound groundwork was now also being laid for the development of bacteriology. Like the study of cells, the recognition of bacteria did not have a sudden beginning. Leeuwenhoek's little animals had been observed again and again. As the quality of microscopes improved, even efforts at morphologic classification of these organisms had been made. Presenting as a fundamental problem always was the origin of these organisms. Did they generate de novo from inert organic material or was such generative power present only in pre-existing organisms? Was there actual contagion as Semmelweis had contended or did these organisms form in the body from damaged tissue and lymph? It was Louis Pasteur who, in a series of elegantly devised experiments, proved for all time that spontaneous generation of bacteria did not exist. For the surgeon this was of tremendous practical as well as theoretical importance. Pasteur's demonstration that the growth of bacteria in a medium occurred because bacteria either were there in the beginning or were brought in by contaminated atmosphere could be applied to the problem of wounds. This caught the attention of a young surgeon in Scotland, Joseph Lister (1827–1912), who immediately associated this phenomenon with the development of sepsis in wounds.

It was fortunate that Lister had been at Edinburgh for his surgical training for the surgical environment was extraordinary. Surgical education in Edinburgh, both at the University and in the extramural school, was never more brilliant than in those years just preceding him. Three men stand out in particular: Liston, Fergusson, and Syme. Robert Liston (1794–1847), unable to obtain a position on the staff of the Royal Infirmary, operated in patients' homes or in rooms that he could provide. By sheer boldness and skill, and helped by his many writings, he became one of the best-known men of his period. Syme often assisted him but their friendship became strained. When Syme was appointed to the chair of clinical surgery at the University of Edinburgh, Liston, who had also desired the position, left for London to become Professor of Surgery at University College. It was there that he performed the first

major operation under ether anesthesia in England, an amputation through the thigh—an operation that he performed in 28 seconds. Although he made many important contributions to surgery, perhaps it was his technical skill that brought him most fame.

William Fergusson (1808–1877) rivaled Liston in his surgical finesse and, like Liston, he also left Edinburgh for London, to occupy the chair of surgery at King's College. In spite of his speed and his technical prowess, Fergusson had the greatest horror of amputation. Perhaps it was because of his great ability that he was able to advocate successfully more conservatism in surgery—wherever possible, local excision was carried out instead of amputation, bladder stones were crushed instead of open lithotomy being performed, and he improved considerably on the cleft palate operation in use at the time.

James Syme (1799–1870), who became head of clinical surgery at Edinburgh in 1833, was another surgeon of extraordinary capabilities, equal to Liston in boldness and similar to Fergusson in his conservatism. Nothing excited him more in surgery than the opportunity to conserve an extremity rather than to sacrifice it. He used ether anesthesia in 1847 and was one of the first ardent champions of antiseptic surgery. And it was by no means because Joseph Lister, a former pupil, had married his daughter. It can safely be said of Syme that he did not subscribe to the nepotism of the Monros.

Joseph Lister received his medical education in London and, deeply intent on becoming a surgeon, went to Edinburgh in order to work with Syme. In 1860 he transferred to Glasgow, and here much of his work on antisepsis took place. Lister tried several substances for use as an antiseptic, eventually selecting carbolic acid, perhaps as a result of its known effect on sewage. His principles were simple. His contention was that wounds became septic because microorganisms were carried to them from the outside. He therefore instituted a system of cleanliness at the operating table, gentleness to tissue, dressings saturated with phenol placed on the wound to destroy accidental contamination, and, later, even a fine mist of phenol sprayed into the air of the operating room to sterilize the atmosphere. He began these studies in 1865 and in 1867 he published his first two accounts in the *Lancet*—studies that were to revolutionize surgery. Lister was able to think clearly and none of his work was abstruse. He recognized the difficulty, even the improbability at first, of excluding organisms from a wound—the use of an antiseptic was therefore necessary. As better methods of protecting a wound would be devised the antiseptic would decrease in value: a fact he realized. There was thus no difference in the principles of antisepsis and those of asepsis, and the controversy that subsequently developed over the two was silly and fortunately was short-lived.

Lister's ideas received firm support from subsequent studies by others. Robert Koch showed that specific organisms which could be demonstrated as being present in infected wounds produced an inflammatory process that was also different, and methods of culture of these organisms were developed. Lister was able to sterilize the catgut ligature and brought it into general use. In 1871, he adapted the use of a drain of India rubber, first employed for the drainage of an abscess cavity by Chassaignac in 1859. The patient on whom Lister first employed this drain was Queen Victoria. This did much to popularize adequate drainage of infected areas, and the rubber drain soon came into almost universal usage. Lister's mortality from amputations fell from 43 per cent to 15 per cent. Von Bergman and his assistant Schimmelbusch, following the lead of Neuber, adapted steam sterilization to surgery in 1886, and by 1891 a ritual of sterile instruments, dressings, and drapes had been instituted in his operating room. In 1890, Halsted began the use of thin rubber gloves; and in 1900, at the Charing Cross Hospital, Dr. William Hunter first used masks of gauze over the faces of the operating team. Asepsis had come of age.

Lister succeeded Syme at Edinburgh in 1869 and later became professor of surgery at King's College in London, a position he held until his retirement in 1896. The career of Lister is one of the most thrilling in medical history.

During that period in which anesthesia and antisepsis were developing, other fields in medicine were also being explored. In physiology, following Magendie in France was Claude Bernard (1813–1878) and in Ger-

many Karl Ludwig (1816–1895) at Leipzig. The effect of these two men on surgery is so far-reaching that it is difficult to evaluate. They stressed the value of research, research methods, and rigorous discipline in the collection of data. Bernard's *Introduction to Experimental Medicine* is one of the classic contributions to scientific literature and to epistomology. Not only were the investigations of these men of great practical importance, but the effect of their teaching on students was even more so. The gastrointestinal tract, the liver, the pancreas, the brain, and the nervous system became the objects of investigation in both normal and abnormal situations. From these studies, along with the impetus in morphologic pathology stimulated by the German group in particular, a true pathologic physiology began to develop and disease was approached from a dynamic reference. Tumors were now classified and their growth and behavior noted. The life history of a lesion could be anticipated and modification that was obtained as a result of surgery ascertained. So was born a new type of surgery.

The field of surgery was rapidly extended as technical development kept pace with basic introductions. For instance, when embolism, infarction, and thrombosis had been elucidated by Recklinghausen, Virchow, Conheim, and others and studies had been made of the coagulation of blood, vascular surgery could develop. The aggressive attack on varicose veins was well presented by Trendelenberg (1844–1894) who also devised and performed an operation for removal of a clot from the pulmonary artery. Asepsis now made open operation on bone possible, and again Trendelenberg performed open suture of a fracture, first doing this on the patella. Specific fractures were being carefully described, distinction from dislocations being insisted upon, and logical methods of reduction developed. The names of Colles, Malgaigne, Velpeau, Bigelow, Madelung, and Buck stand out. Brodie (1783–1862) demonstrated the clinical picture of acute hematogenous osteomyelitis and the advisability of open drainage in the treatment of this disease.

It is obvious that, until aseptic surgery was well developed, neurosurgery could not become too extensive. Wounds of nervous tissue must of necessity heal by primary intention. In neurosurgery, infection always spells disaster. The effect of trauma was therefore first developed. Gama, in 1830, presented a treatise on head injury in which he had performed experiments demonstrating lines of force following a blow to the head and as a result of this work assumed a microscopic disruption in the continuity of nerve tissue and blood vessels. Cerebral localization was still fragmentary; the clinical recognition of intracerebral hemorrhage haphazard. Following the impetus given by Bell, peripheral nerve lesions were becoming more easily recognized and during this period well-known surgical names—Pirogoff, Dieffenbach, Broca, Lucas-Championière, von Volkman, Keen, and Victor Horsley—began to appear in association with lesions of the nervous system. Keen and Victor Horsley actually belong in what we should consider the present period.

Since anatomic teaching was almost completely in the hands of the surgeons, it was natural that more detailed anatomic attention would be given inguinal and femoral hernia. Also, since surgical speed was no longer as essential, structures previously noted at dissection could be examined more thoroughly at operation. Herniotomy thus gave way to herniorrhaphy. The names of Scarpa, Camper, Colles, Gimbernat, Cooper, and Hesselbach came back into common usage. In 1890, Bassini (1844–1924) presented his method of hernial repair which has become classical.

Thoracic surgery exemplifies nicely the dependence that surgery has upon advances in physiologic knowledge. While Fowler, in 1893, performed a partial thoracoplasty to obliterate dead space left following removal of a tumor of the chest and Delorme, in 1894, recommended pulmonary decortication in certain patients with chronic empyema, thoracic surgery was greatly curtailed in its development until better understanding of intrathoracic pressures came about. This did not receive adequate treatment until the work of Evarts Graham and E. T. Bell in 1918; up to that time the thoughtful surgeon rarely entered a free pleural cavity.

The most spectacular advances were in abdominal surgery. It was not that the abdomen had not been opened previously and various viscera removed, for this had taken

place frequently in the eighteenth century. The mortality was extremely high, however, and most responsible surgeons leaned toward the side of conservatism. The story of appendicitis serves as a good example of the change in approach. Many of the important features relating to appendicitis were well known in the eighteenth century but were not particularly stressed because of therapeutic impotence. The term "iliac passion" for the acute abdominal catastrophe had long gone out of use. In 1839, Addison described the course of appendicitis very well, and appendicular abscess had previously been drained. The pathologic findings developed by Fitz in 1886 were well timed to fit the institution of adequate therapy, and appropriate surgery could then be developed by McBurney and others. This illustrates that rationalization in therapy needs the presence of basic information and co-ordination of this knowledge with new concepts of pathogenesis before effectiveness in therapy can be obtained.

William Beaumont (1785–1853) had demonstrated not only that survival was possible with gastrostomy but had studied on his patient, Alexis St. Martin, many aspects of gastric secretion. His findings were of such practical clinical value that today they are still being referred to. Gastrostomy was performed in 1858 by Forster in London; in 1877, Billroth described the procedure. Resection of the pyloric portion of the stomach was performed by Péan in 1879 and by Rydgier in 1880. These were unsuccessful. A successful resection of the pylorus for cancer was performed by Billroth in 1881. As a matter of fact, that same year Wölfler (1850–1917), a pupil of Billroth, described three cases that Billroth had done and one that he had performed. Wölfler is best remembered for his operation of gastrojejunostomy done in 1881. Gastrointestinal surgery developed so rapidly that it would be difficult as well as inaccurate to portray individual contributions. Three names should be mentioned, however, for these men and their pupils did much—Langenbeck (1810–1887), Billroth (1829–1894), and Kocher (1841–1917). They made many original and daring contributions to surgery. They were great teachers and, through their influence, German surgery dominated during the last part of the nineteenth century. They were good anatomists, they were excellent pathologists, and they were cognizant of the latest in physiology and chemistry and ready to apply these principles to surgery. As histologic studies in morbid anatomy developed, they could make contributions in this field for they saw the early lesion and they knew their subject. The surgery of cancer developed under their tutelage. The consideration of surgery as something beyond an extirpative art and the surgeon as more than a craftsman was never better exhibited. It was this spirit that spread to surgery throughout the world. Surgical journals came into being; surgical societies became commonplace. As achievements accumulated, therefore, those of value were immediately adapted to surgery throughout the world, whether a discovery in physics, as that of x-rays, or whether the adaptation of ideas, as the physiologist Ludwig's notion about the use of salt and sugar solutions parenterally. Such developments really represent the essence of modern surgery and perhaps our story could well end here.

It is trite to say that greater progress has taken place in surgery during the past century than in the previous 50 centuries combined. Nevertheless, it is true. An analysis of the background of this progress brings out, I think, certain salient features worth thoughtful consideration. Perhaps the single factor most important in bringing about this achievement has been the use of controlled observations. Observations alone were not enough. Observations, and even reflections, often led astray. Observation, reflection, and experimentation, however, made surgery a science. It also can be seen, though, that surgery is a science existing in almost an ancillary capacity subservient to contributions from many other scientific disciplines. Until the surgeon learned these other disciplines, casually referred to today as "basic science," he could not develop his experimentation. It seems apparent that the same forces at play in the development of this phase of medicine called surgery are also intimately concerned in the education of a single individual who elects to practice it. If this be true, the surgeon must know the essence of a controlled observation and he must have the fundamental knowledge of biologic and physical processes

by which the human body functions. Without this knowledge he may become a craftsman, even an adept one. He will not be a surgeon.

Another thing seems obvious. Individuals made great contributions, often calling for intellectual and moral effort of a high degree. No great contributions were made by committees or teams. Knowledge as encompassed in a single person made for these great achievements. We must always become disturbed, therefore, when we practice a type of surgery that is not individualistic and that requires "borrowed brains"—an internist and a radiologist to make our diagnoses, a pathologist to interpret our lesions, and a resident staff to take care of our patient after operation.

The surgeon must not only acknowledge his scientific obligations but, in addition, must recognize and accept the social responsibility that they carry. These and other things we learn from the history of surgery.

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THE SURGICAL HISTORY AND EXAMINATION

J. Englebert Dunphy

THE SURGICAL HISTORY

Modern surgery is both an applied science and a healing art. The surgeon—equipped with a broad knowledge of anatomy, bacteriology, chemistry, pathology, physiology, and surgical technique—undertakes to correct or ameliorate the abnormalities produced in the human organism by injury or disease. In this sense, he is an engineer. But, in applying his knowledge, the surgeon is ministering to the sick in a very special, positive, and, at times, ritualistic way. In this sense he must accept a role similar to that of minister or priest. It is thrust upon him by the anxious sick who want sympathy and understanding fully as much as they want to be cured. The fundamental dignity of man places an obligation on the surgeon to recognize and fulfill this dual function. The taking of a history and the performance of a physical examination are the first steps towards this accomplishment.

The effective application of whatever scientific knowledge the surgeon possesses is entirely dependent upon the history and the examination of the patient. This is true even in conditions that can be recognized by a single x-ray or laboratory test, because the biologic responses of the human organism to injury or disease are so variable that careful and repeated review of symptoms and physical findings is an essential part of the scientific appraisal upon which treatment depends. For this reason, laboratory tests will always be adjuncts to the history and the physical examination. A scientist at the bedside who cannot apply his knowledge effectively is as bad as a charlatan who has no knowledge to apply. Indeed, he is worse, because the charlatan may at least provide encouragement and sympathy, which are as much a part of good surgical care as is the skillful performance of an operation.

A basically well-grounded medical scientist can become a competent surgeon only if he acquires the clinical skill, acumen, and judgment that comes from extensive experience with the care of patients. He must learn to see, hear, feel, and smell. He must concentrate on knowing the normal in order to recognize the abnormal. He must not allow the slightest detail to escape him and he must see in his patient a frightened, disturbed human being, who often can be made well only if he can be understood and treated with compassion and sympathy as well as with skill.

Taking the History. The objectives of taking the history are threefold. 1. To learn all the facts concerning the patient's present illness and past history and to assemble and record them in an orderly and understandable manner. 2. To measure the patient as an individual, which means learning something about his job, his family, his background, his hopes and ambitions, and the type of person he is. Frequently, the decision to operate or the selection of the type of operation required depends upon this information. 3. To inspire confidence by making the patient realize that the surgeon is interested in him and his health, rather than in his disease or injury.

In taking a history several points are important: It cannot be hurried. Both examiner

and patient must be at ease. It is futile to question in detail the patient who is emotionally upset or in severe pain. In certain emergent situations the initial history may be obtained in a few seconds, i.e., "hit by a car" or "swallowed a pin." Under such circumstances the examination will be similarly curtailed and focused. Particular points with reference to the "emergency examination" are described later.

The Chief Complaint. Usually the principal complaint of a patient with a surgical disease stands out very clearly—pain in the abdomen, bleeding from the bowel, a lump in the breast. At times, however, the patient's interpretation of the meaning of the symptoms may cloud the issue. Thus, he may complain of "kidney trouble" when he has a pain in the loin, or "pain in the breast" when the basic trouble is a fear of cancer. Indeed, a patient may deliberately withhold the chief complaint in the misguided hope that if the physician does not find something wrong in his examination, the symptoms are not serious. Many amusing incidents have been recorded about the patient's chief complaint. Too jaunty an approach, "Well, what's the matter with you?" may elicit the justifiable reply "That's what I have come to find out!" A misinterpretation of the patient's stated chief complaint may set the examiner off on the wrong track, as in the extreme and apocryphal example of the pregnant lady who was sent to the Eye Clinic because she said she had not seen anything for three months.

Present Illness. Once settled upon, the chief complaint is the focal point for eliciting the facts of the present illness. Duration, exact character, mode of onset, related signs and symptoms, disturbances of function in other organs and systems—all of these must be ferreted out, assessed, and placed in their proper perspective. A good history taker must have a bit of Sherlock Holmes or, perhaps better, of Father Brown in him. It is incredible how ingenuous and misleading some patients may be. An old gentleman may deny getting up at night to urinate without divulging the fact that he customarily takes a urinal to bed with him. If a patient is asked if he has seen blood in his stools, he may justifiably reply in the negative, because he has never observed his stools. Such foibles are familiar to every good examiner and are easily avoided.

The importance of a careful analysis of symptoms by history taking cannot be overemphasized. Consider, for example, the difference between knowing that a patient has had "midabdominal and epigastric pain for six hours" and knowing that a patient has had "abdominal pain which began in the epigastrium as a mild intermittent colic, gradually settled in the right lower quadrant of the abdomen and became steady and severe." In the first instance, the examiner can draw no conclusions regarding the significance of the pain. In the second, he has good grounds to be strongly suspicious of suppurative appendicitis. Pain is such a common and revealing surgical complaint that it always merits very careful analysis. When it began, how it began, its exact nature, its severity and its radiation, and its relation to such other symptoms as a desire to urinate or defecate are details which must be precisely elaborated.

Similarly, if the patient has vomited, the details must be determined. How often? How much? Was there nausea? Was it projectile? What was in the vomitus? A loss of blood is such a frightening experience that the patient may exaggerate the amount. Here, there is nothing better than for the surgeon to see the specimen personally. The presence of a tumor or ulcer requires specific analysis for which leading questions may have to be asked. Has the tumor changed or varied in size? Was there an injury? Is it painful?

A history of trauma is so frequent in surgical diseases that it cannot be taken at its face value unless the relation between the inquiry and the complaint is definitely established. Most individuals, particularly in describing the illnesses of children under their care, will connect an injury with the beginning of symptoms since it makes the cause easy for them to understand. The average person cannot believe that disease may start in some spontaneous or occult manner and, hence, searches his memory for some initiating episode. He may implicate any event immediately preceding his illness. Trauma is so common, particularly in children, that its relationship to a specific complaint is often unreliable. On the other hand, serious trauma may be sustained by infants and young chil-

dren without the parents being aware of it.

When there is a history of trauma, it is most important to reconstruct the exact details of the accident. Where was the patient when the accident occurred? How was he thrown and did he lose consciousness? Retrograde amnesia, inability to remember the events just preceding the accident, is a sign of the utmost importance because it indicates some degree of cerebral injury. If a patient can remember all the details of an accident, has not lost consciousness, and has no external injury to the head, it is possible to exclude head injury. On the other hand, retrograde amnesia or transitory loss of consciousness may be the only initial signs of what may prove subsequently to be a serious head injury, particularly one associated with extradural or subdural bleeding.

In penetrating wounds, it is of great importance to know the trajectory of the missile. This may provide conclusive evidence that a particular viscus cannot have been injured, or it may indicate probable damage to an organ which, from a casual study of the wounds of entrance and exit alone, might not be considered as being involved. Many times such details of accidents cannot be obtained, and one must not waste time in fruitless efforts to establish data which are not available, because of the gravity of the injury. In compound fractures, the entire course of therapy may be influenced if the surgeon can determine the time element between injury and entrance to the hospital, the kind and degree of contamination (whether the wound was sustained outdoors in a fertilized field, on a highway, or in a home), and especially whether the clothes of a patient protected the wound or were carried into the wound.

One must not overlook the effect of other diseases in trauma and accident. A history of epilepsy, diabetes, or coronary artery disease may provide crucial data, both as to the reasons for and cause of the accident and to the condition of the patient. There are well documented instances in which diabetic patients have been thought to have serious head injuries or to be inebriated, until it was established that they had neglected to eat after an injection of insulin.

When all the data referable to the present illness have been obtained, they must be set down in an orderly fashion. In doing so, apparently unrelated symptoms may fall into their proper perspective and a clue may be obtained to a specific disease which might otherwise be overlooked. Occasionally, after writing up a history, the examiner will find a detail missing which, if positive, would alter the entire interpretation of the illness. This commonly occurs in the examiner's formative years, and he should never hesitate to return to the bedside to review in detail the nature of one or more of the patient's complaints. Moreover, the exact details of this illness may assume great significance at a later time when the patient re-enters the hospital for treatment of either the same or an unrelated disease.

Family History. The family history provides general information regarding the patient and his family that frequently reveals more of the patient's personality. It is important also with reference to certain specific diseases. Jaundice, polyposis of the colon, diabetes, various pigmentation syndromes, certain abnormalities of the pancreas, and a variety of other conditions may have familial tendencies. The family history may make it evident that other members should be brought into the hospital for study and treatment. Although less important than in the past, a history of infectious diseases, particularly tuberculosis and syphilis, provides important diagnostic clues. Thus, stillbirths and miscarriages occurring without obvious cause may be associated with untreated syphilis.

Past History. The past history of a patient's health is of vital importance for two reasons. First, it may provide an essential clue to the correct diagnosis of the present illness. Thus, an unexplained retroperitoneal mass may be related to a "small, black mole removed from the leg seven years ago," or a "little x-ray treatment for acne" when the patient was a child may be the etiologic factor in recurring carcinoma of the skin. Apart from revealing specific factors of importance in the diagnosis of the present illness, the past history reveals an important view of the whole patient. His tendency to be ill, his reaction to previous disease or injury, and the time of onset of various metabolic or endocrine disorders are vitally important. Thus, it is essential to know how long a patient has had diabetes, what

complications have set in, and what treatment he has received. All of these have a direct bearing on the patient's probable reaction to his present illness and to an operation, should it be found necessary. In many instances, a careful taking of the past history will bring out symptoms of some unrelated systemic disease which requires correction before the presenting complaint can be treated. A classical example is the discovery of prostatic hypertrophy in a patient complaining of a hernia. Carcinoma of the colon is also discovered frequently as the "hidden disease" behind the patient's complaint of a hernia or pain in the incision of an old operation.

The examiner must have a set pattern for eliciting the details of the past history in order to avoid overlooking important points. It is extraordinary how frequently a patient will deny ever having been ill but, on direct questioning, will suddenly recall symptoms or even a specific illness directly related to the present complaint. Lest important details be overlooked, the following routine is recommended:

PAST HISTORY

1. *Previous illnesses:* Childhood diseases, tuberculosis, cancer, jaundice
2. *Previous injuries*
3. *Previous operations*
4. *System review:*
   a. Neurologic: headache, fainting spells, dizziness
   b. Cardiovascular: previous history of cardiac disease, dyspnea on exertion, orthopnea, precordial pain
   c. Gastrointestinal: digestion, bowel habits, melena, constipation, diarrhea
   d. Genitourinary: frequency of urination, dysuria, hematuria, pyelitis
   e. Catamenia: time of onset of periods, duration of flow, intermenstrual bleeding, associated symptoms
   f. Endocrine-metabolic: weight, growth of hair, secondary sex characteristics
5. *Nutritional history*
6. *Psychiatric history*

Space does not permit a detailed analysis of the technics of history taking in each of these various systems and the student is urged to consult textbooks of physical diagnosis for such information. However, because of their direct bearing on surgical problems, two aspects of the past history, the nutritional and the psychiatric, will be discussed in more detail.

Nutritional History. A commonly held belief that the average person will naturally select a well-balanced diet is now thoroughly discredited. Ample studies have shown a disturbing incidence of nutritional deficiencies among those who consider themselves well and among the sick, the percentage of course rises sharply. The reasons are many: personal preferences, ignorance, prejudice, alcoholism, and poverty. Tradition and habit are also frequently responsible for the consumption of an obviously deficient diet. Although most of these deficiencies cannot be recognized by clinical manifestations, the physician can suspect their existence from the history and establish their degree by various chemical methods.

In obtaining a nutritional history, one should determine whether the patient consumes a generous and varied diet or eats sparingly of the same groups of foods. Detailed questions are necessary, for example: Does the patient take a fair amount of good proteins such as milk, meats, and eggs? Are vitamin-containing foods such as fruits and vegetables, milk, butter, and meat consumed regularly? The fact that the patient is of normal or even of excessive weight does not necessarily exclude the possibility of nutritional deficiencies, particularly in vitamins and proteins. In such cases, the normal or high body weight is merely a manifestation either of edema or of large fat deposits. Indeed, there is evidence that an unbalanced diet, heavy in carbohydrates and deficient in proteins and fats, may lead to obesity. On the other hand, a history of a loss of weight indicates tissue loss. This may be of adipose tissue, and less significant than a loss of protein which implies physiological impairment.

Even if the patient has eaten a normal diet and has been well nourished, malnutrition is prone to follow shortly after the onset of many surgical diseases. The existence of such deficiencies may usually be taken for granted if there is a definite loss of weight. A knowledge of the kind of foods which have been omitted may be helpful in determining the nature of a deficiency.

Acute nutritional deficiencies, particularly

with reference to loss of fluid and electrolytes, require specific and detailed attention. Laboratory data, such as the serum levels of sodium and potassium, can be interpreted only in the light of such information, and the serum levels of electrolytes may be quite misleading unless the sequences of the nutritional history are carefully recorded. The interpretation of a lowered serum sodium depends upon knowing whether the patient is suffering from heart disease, whether he has been given a sodium-restricted diet or diuretics, and whether he has had a restricted intake or acute excessive loss of fluids from the body. If there has been vomiting or diarrhea, the character and quantity of the lost fluid provide essential information on which sound estimates of the probable type and extent of electrolyte deficiency can be based. Thus in protracted vomiting, if one knows whether or not the vomitus contains bile, he immediately has some idea of the level of the gastrointestinal tract from which fluid is being lost, a matter that relates directly to the electrolyte composition of the losses.

Early in his career, the surgeon must learn to think in terms of "nutritional balance." The elements exchanged and utilized in daily diet and metabolism—nitrogen, sodium, potassium, and chlorine—as well as caloric energy, are of established importance, and there is increasing evidence that magnesium and other elements will be added to the "balance" list.

A knowledge of the probable concentration of electrolytes in body fluids, particularly under circumstances in which there is a large loss of fluid from the body as in vomiting or an external fistula, is part of good surgical care. It may be necessary to determine the precise concentrations by chemical analysis, but the surgeon should not have to wait for laboratory data before beginning the treatment of a patient who has been vomiting from intestinal obstruction. Knowledge of the level of obstruction and of the concentration of electrolytes in the gastrointestinal fluids above this level provides sufficient information for the institution of immediate therapy. The details of management of such problems and the importance of history taking in their appraisal are more fully presented in chapter 9.

Psychiatric History. A good clinical history is not complete unless it contains information about the patient's personality. Such information may be limited to a word or two, or it may extend to a paragraph or many pages involving some of the most intimate details of the patient's life. This material forms the background for the interpretation of the patient's symptoms. The old-fashioned family doctor knew these facts and was able thereby to achieve excellent therapeutic results in many instances without the benefit of modern technics. It is improper to relegate responsibility for knowledge of these facts to the psychiatrist. Although there are many instances in which psychiatric consultation and advice is essential in the management of patients with surgical diseases, in a majority of instances the surgeon must provide the personal interest and sympathy which every human being requires when ill. Failure to do so is unjustifiable. This concept applies most particularly to patients for whom surgery fails, as in inoperable carcinoma, or to patients in whom surgery produces an abnormality which requires special care and attention. Patients with ulcerative colitis requiring colectomy and a permanent ileostomy fall into this category. Only the surgeon can provide the proper advice, guidance, and sympathy in the handling of an ileostomy. It is unthinkable to refer such a patient to a psychiatrist for help in readjustment to the presence of a gastrointestinal stoma.

There may at times be patients who, because of basic psychiatric difficulties, require additional help in adjustment and for whom only specific psychiatric care will be beneficial, but the majority of surgical patients will do far better if the surgeon himself assumes this responsibility.

THE SURGICAL EXAMINATION

The surgical examination consists of several parts: the physical examination, which may be an elective or an emergency examination; laboratory tests and special examinations; x-ray examination; and follow-up examination. Each of these parts is essential to the whole, and today none can be omitted in the study of a complicated injury or disease. Nor can one part of the examination be substituted for any other. Laboratory and x-ray examinations cannot be accepted in lieu of a

careful physical examination. Each portion of the surgical examination has its own particular role and place.

The extent of each part of the surgical examination obviously varies with the condition under study. This applies to the physical examination, many special steps of which may be omitted. For example, a detailed neurologic examination is not ordinarily required in the appraisal of a patient with acute abdominal pain but, under certain circumstances, it may become a crucial factor because of evidence suggesting a cord tumor simulating acute abdominal disease. Similarly, every patient entering a hospital today should have an x-ray examination of the chest, but the need for more extensive radiologic study depends upon particular indications. When serious errors occur in the care of patients today, they are more frequently related to errors of omission or misinterpretation of physical signs than to misuse or failure to utilize laboratory or x-ray data effectively.

Each part of the surgical examination will be discussed separately and some generalizations *regarding its indications and use will* be made.

Physical Examination. A clear distinction must be made between the elective physical examination, which can be done in an orderly, precise, and detailed fashion, and the emergency examination, which must be restricted to certain steps because of the condition of the patient. The elective examination will be considered first.

A. Elective examination. The elective physical examination of a patient must be complete. The ability to do an elective examination and to know that no step has been inadvertently or deliberately omitted is acquired by careful, repeated performance of the complete physical examination according to a set routine. Such a routine is described in standard texts on physical diagnosis and is often included as part of hospital records. In his early years the student must adhere to some such outline so that he acquires the ability to carry out a complete examination without conscious effort. Only by doing this can he avoid making inexcusable errors of omission.

A second vital feature of the physical examination is that it must be well done. It is useless to go through the process of inspection, palpation, and auscultation unless it is done with infinite care. As he performs the individual steps in the physical examination, the surgeon should have as his objective the detection of normal anatomical structures and the variations which have been produced in them by pathological lesions. He is seeking to detect with his eyes, fingers, and ears the physical alterations produced in the human organism by injury or disease. He cannot do so unless he is thoroughly familiar with the normal. For this reason, there is nothing so valuable, in the surgeon's early years, as the performance of many so-called "negative" physical examinations. If these are performed carefully and conscientiously, with the objective of familiarizing oneself with normal anatomic structures and landmarks, the basic groundwork for the recognition of the slightest abnormality is established.

In the performance of the physical examination, every effort must be made to have the patient comfortable and at ease. This is also an excellent time for the surgeon to learn *more about the type of person he has for a* patient. Specific points in the history may be reviewed even as the patient is being examined. Indeed, at times it relaxes the patient to be able to continue to talk about his troubles at this point. This is particularly true of young adults and children. At the same time, attention should be directed toward the patient's facies for evidence of pain, pallor, jaundice, cyanosis, plethora, and so on.

As one proceeds to the complete physical examination, it is essential that the patient be completely stripped of clothing, but that appropriate draping be provided to allay embarrassment, particularly in female patients.

After assaying the patient's general appearance and habitus, it is a good custom to examine his hands next. Many important diseases are revealed in the hands, among them hyperthyroidism, Raynaud's disease, cirrhosis of the liver, and pulmonary ostearthropathy.

Although temperature, pulse, and respiration are frequently recorded by a nurse or attendant, it is essential that the surgeon feel and appraise the pulse, and, at times, also take the blood pressure.

One now proceeds in an orderly fashion to

the complete physical examination beginning with the head and neck, and proceeding to the extremities in accordance with an established routine. Obviously it is impossible to review here each aspect of this examination but certain features merit brief emphasis. Every local lesion should be appraised in the following order: inspection, detection of alteration of function, palpation, and frequently auscultation.

1. *Inspection.* Since it occasions no pain, inspection is always carried out as the initial step in an examination. As the examiner looks at the lesion, he should consciously ask himself what pathologic changes may account for the noted alteration in color or contour. He should think of the abnormality not as an amorphous mass of human tissue, but as a specific alteration produced by disease in skin, muscle, bone, or blood vessel. As he looks at the base of an ulcer, an image of the probable histologic appearance of the lesion should come into his mind.

At times, minor variations may be detected by comparing symmetric portions of the body, as in the examination of the breast, where a little fullness of one breast may be a lead toward an ill-defined infiltrating tumor. A slight droop of the corner of the mouth in a patient with a tumor in the parotid gland may be the clue to the presence of carcinoma rather than of a mixed tumor. The mere droop of an eyelid may be the telltale sign of an infiltrating carcinoma of the lung with involvement of the cervical sympathetic nerves. The recognition of a disease or an abnormality by precise inspection alone is always an exciting experience. Frequently the information so found can be secured in no other way.

2. *Palpation.* Palpation, if carried out skillfully and gently, furnishes a great deal of information. If improperly done, it may so completely alienate the patient that further examination is impossible. Avoidance of pain is the key to successful palpation, yet the elicitation of tenderness is one of its important objectives. Thus, gentleness is of crucial importance. The manner in which the surgeon first places his hand on the patient sets the stage for success or failure. Roughness will antagonize; gentleness will inspire confidence and assure relaxation and co-operation. During palpation, one should watch the facial expression of the patient closely. It may be possible to divert the patient's attention during the examination so that more accurate and objective reactions can be produced. This is especially the case in the examination of children. When attempting to elicit tenderness, one must palpate with one finger only. Palpation with the entire hand produces too wide an area of pressure to permit a precise localization of the tenderness. This applies to all conditions but is essential in the presence of acute abdominal disease.

3. *Palpation of the acute abdomen.* Palpation of the acute abdomen has three objectives: to detect spasm of the abdominal musculature; to localize areas of tenderness; and to outline and identify, if possible, organs and masses. To distinguish between voluntary and involuntary spasm of the rectus muscles, the flat of the hand should be placed gently on the abdominal wall and kept in contact with it, while gentle pressure is exerted on it with the right hand. A distinct resistance can be felt if there is spasm. If the patient is then asked to take a long breath, voluntary spasm will disappear momentarily whereas involuntary or true spasm will persist. Attention is again directed to the importance of outlining areas of tenderness by means of "one-finger palpation." For the details of abdominal palpation with reference to organs and various tumors, the reader is again referred to other texts.

4. *Alteration of function.* Alteration of function of a part may give important information and, at times, should be elicited as a part of inspection because it may inflict no pain. On the other hand, if there is a question of a local injury it may be better to palpate before asking the patient to move an extremity. Detection of alteration of function is the preferred method for determining the presence or extent of injury to nerves. Limitation of movement may also be caused by fibrosis, ankylosis, muscle spasm, or pain. The extent of the spread of tumors to soft tissue or bone may sometimes be appraised on the basis of the alteration of function which they have produced.

5. *Auscultation.* Auscultation is as important in surgery as it is in medicine and is particularly valuable in the appraisal of abdom-

inal injuries, acute abdominal disease, and postoperative abdominal states. It is also a useful and valuable habit to auscultate swellings and tumors anywhere in the body. It is amazing how frequently a vascular lesion will be first detected on the basis of auscultation rather than palpation.

6. *Examination of the various body orifices.* This is a part of every complete examination. There is now a general acceptance by patient and physician of the need for rectal and pelvic examination. It is curious, however, that there is a continued failure of many examiners to appraise the mouth carefully. Palpation of the floor of the mouth and the tongue is an essential part of the complete study of any lesion within the mouth. It is also vitally necessary in the appraisal of glands in the neck. Because it may cause discomfort to the patient, particularly during palpation of the base of the tongue and tonsillar fossae, it may be properly postponed until the rest of the examination has been completed.

Finally, the use of the ophthalmoscope and the sigmoidoscope is an essential part of a good physical examination. *It is poor medical* practice to order an x-ray of the skull in the appraisal of headache without first having performed an ophthalmoscopic examination. Similarly no patient should be referred to the radiologist for a barium enema who has not first been studied by means of the sigmoidoscope. These examinations should be a regular part of the examiner's armamentarium and should be used with great regularity if not routinely.

B. Emergency examination. The seriously injured or very acutely ill patient requires an approach different from that in the ordinary elective examination. The history must of necessity be curtailed, and in serious injuries may be limited to a phrase such as "struck by a car" although, as mentioned earlier, the details of the accident are most important in studying the extent and character of the injury. The acquisition of this information, however, is often of secondary importance to immediate life-saving measures. Whether the examination is performed on the battlefield, in the hospital, or on the roadside, the general principles are the same.

The first consideration must be: *Is the patient breathing and has he an adequate airway?* If the patient is not breathing, correction of the situation may consist simply of turning him on his side, face down, and pulling out his tongue so that he can breathe. Simple aspiration or wiping of blood or mucus from the mouth may be sufficient. In some situations, emergency endotracheal suction or tracheotomy may be required; in others, artificial respiration may be necessary.

The second consideration, which may take precedence over all others because of its visible presence, is *the serious loss of blood.* It is often evident at a glance that the patient has no respiratory difficulties, but that he is bleeding massively from an extremity. Here, local pressure over the wound or a tourniquet may be required.

Once an adequate airway has been established and massive external bleeding controlled, a rapid survey of the entire patient must be made. The student is referred to textbooks on physical diagnosis for details of this examination, but it must be emphasized that the most serious mistakes have been made where, because of the presence of *an obvious lesion which seemed to account* for the patient's shock, an inadequate and incomplete physical examination was performed. It takes only two or three minutes to carry out a rapid but careful examination of the head, thorax, abdomen, and extremities and to turn the patient gently on his side so that the back can be inspected. Failure to do this survey examination may result in a patient being treated for an obvious fractured hip when in fact, he is also bleeding from a penetrating wound of the buttocks or peritoneum. Tension pneumothorax, cardiac tamponade, and certain open, sucking wounds of the chest are easily overlooked in the face of multiple injuries unless this routine is followed. Once an extent of the injuries has been obtained by this rapid survey technic, attention must be given to the splinting of limbs, the control of pain, and the treatment of shock.

THE LABORATORY EXAMINATION

Inspection of the Urine, Stool, and Vomitus. Simple inspection of the urine, stool, and vomitus by the surgeon is often an important part of the laboratory examination. Much

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here that ancillary methods of study, such as sigmoidoscopy and gastroscopy, can be used as supplements to x-ray examination.

The final responsibility for the interpretation of data furnished by x-ray rests with the surgeon. In many instances, x-rays must be repeated because they do not fit with the clinical data. At other times, x-rays must be repeated over a period of time in the hope that early suspicious lesions may be detected on subsequent examinations. Finally, there are occasions in which surgery must be done or withheld contrary to an impression given by the roentgenologist.

There are many special technics in radiology such as cholecystograms, intravenous cholangiograms, operative cholangiograms, angiocardiograms, arteriograms, laminographs, the injection of sinuses, and special methods of examination of the bowel such as double contrast enemas. With these, once again, the surgeon must, by constant association with the roentgenologist, understand the indications and limitations of these examinations. For example, he should know that neither cholecystograms nor intravenous cholangiograms are of value in the deeply jaundiced patient and that an intravenous pyelogram or an intravenous cholangiogram is not a satisfactory measure of renal or gallbladder function. The innumerable situations which may lead to nonfilling of the gallbladder in cholangiography must be known to the surgeon. Frequently, this information is not supplied to the roentgenologist and he may erroneously report a nonfunctioning gallbladder as pathologic.

Good patient care cannot be accomplished by simply referring the patient with a request for a specific examination to the roentgenologist. Repeated consultation and joint review of films and the associated clinical circumstances are prerequisites to good x-ray diagnosis.

SURGICAL PATHOLOGY

Examination of tissues removed at operation or removed by special biopsy technics and study of smears for cellular changes provide important information upon which surgical therapy is based. Many times, histologic diagnosis must be in the possession of the surgeon before he can make a final decision regarding therapy or prognosis. Frequently important decisions also rest upon the ability of the surgeon to identify lesions by gross examination at the operating table. On some occasions, as in breast tumors, the surgeon must make his decision on the basis of a section of the tumor which is frozen and studied by immediate microscopic analysis.

A sound training in surgical pathology is part of a modern surgeon's education. He must continually improve himself by a study of the surgical pathology in each case in which he is involved.

On the other hand, too much weight can be placed upon the pathologist's interpretation of histologic findings. If the pathologist is not furnished with all the details of a case, an erroneous interpretation may be returned. For example, a juvenile mole may be histologically interpreted as a malignant mole. The responsibility for avoiding such errors rests entirely with the surgeon. He must be aware of the fact that there is not a close correlation between the biologic behavior of neoplasms and their histologic appearance. Such correlations can be made only in a very broad way by the pathologist. The final decision as to whether a specific tumor should be treated by x-ray, surgery, or a combination of both rests with the surgeon. For this reason, no surgeon should undertake the treatment of cancer who has not familiarized himself with all the implications of surgical and tumor pathology.

The surgeon should study the microscopic features of each specimen he has removed in order to correlate them with the gross appearance and with the rest of the clinical picture. This is particularly vital in his early years because only in this way can he bring to his work all the knowledge necessary to raise his professional proficiency to its highest plane. It is largely because of these considerations that many of the surgical diseases discussed subsequently will be illustrated by photographs in which gross specimens as well as photomicrographs show the important features of their surgical pathology.

FOLLOW-UP EXAMINATIONS

The high percentage of excellent results following most surgical therapy at the present

significant data may be obtained in this manner which may be overlooked if the specimen is sent only to the laboratory. The character, color, and amount of vomitus are often recorded inaccurately, but if a specimen is saved and the surgeon himself inspects it, precise information is obtained. Similarly with sputum. The specimen should be preserved as well as sent to the laboratory for study. The well-trained, skillful surgeon may detect, in various excretions or discharges, signs overlooked by a laboratory technician. For example, the detection of sulfur granules in the discharge from a chronic sinus may be the key to the presence of actinomycosis.

Whenever the surgeon performs a rectal examination he should inspect the stool removed on the examining finger and place a bit on filter paper to examine for occult blood. More and more this is becoming a routine procedure in surgeons' offices and in hospital wards and is proving an important clue to the early detection of asymptomatic carcinoma of the bowel.

It is frequently stated today that the importance of laboratory tests is overemphasized. This is fallacious. There can be no overemphasis of the importance of laboratory tests because they are crucial and vital to the recognition of certain diseases and in the careful daily appraisal and correction of others. There is all too frequently, however, a great misuse of laboratory tests. Merely because the proper facilities are available is no reason why every patient should have daily sodium and potassium determinations of the blood. On the other hand, the surgeon must be familiar with the minimal requirements and with the need for and meaning of certain tests when they are indicated.

Every patient undergoing a surgical operation should have a complete examination of the urine and blood. In older patients, it is wise to obtain a routine blood urea nitrogen or nonprotein nitrogen. Azotemia commonly accompanies a variety of surgical conditions without revealing its extent by specific signs or symptoms. Moreover, some patients with chronic pyelonephritis will have varying degrees of nitrogen retention without proteinuria.

Special laboratory studies are essential in the appraisal of specific conditions such as the differential diagnosis of jaundice or hypertension, the fluid and electrolyte requirements in patients with diarrhea and vomiting, or the appraisal of diabetes. Many specific tests and examinations may be required, including the determination of the basal metabolic rate, the rate of uptake and the distribution of radioactive iodine by the thyroid gland, and studies of pulmonary functions. The surgeon cannot be regarded as properly trained and equipped to deal with major surgical conditions unless he is qualified to interpret the results of these examinations. It is a mistake to rely on a research colleague or a medical consultant for regular guidance and interpretation of laboratory data. There are many instances in which consultation will be required, but the management of the patient from the point of view of surgical care is the responsibility of the surgeon and cannot be delegated. He is the only one who is able to interpret the meaning of laboratory tests in the light of other features of the case, particularly physical signs.

Special Examinations. In surgical patients, there are many special examinations with which the surgeon must be familiar and of which he must understand the use and application. Cystoscopy, esophagoscopy, gastroscopy, and bronchoscopy are but a few examples of procedures to which every patient need not be subjected but which, when indicated, provide information of great importance.

X-ray Examination. Modern surgery is so dependent upon x-ray examinations that very close rapport must exist between surgeon and radiologist. It is a common error, however, to attach too much significance and precision to x-ray examinations. This applies particularly to studies of the gastrointestinal tract, in which even the best radiologist is working at a considerable disadvantage when he attempts to demonstrate small polypoid lesions or minute craters in the mucosal surface of the stomach, small bowel, or colon. It should be clearly understood, therefore, that negative x-ray reports do not provide assurance of a normal gastrointestinal tract. Conversely, even the best of roentgenologists will occasionally find apparent filling defects in the stomach and the rectum where the diameter of the gastrointestinal tract is largest and the most difficult to examine. Fortunately, it is

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LABORATORY AIDS IN SURGERY

OSCAR CREECH, JR., AND EDWARD T. KREMENTZ

The mature surgeon has a three-dimensional concept of disease which is evolved from the combination of symptoms, physical signs, and findings at operation. Often this results in a better understanding of the relationship between clinical manifestations and pathologic processes than that of his nonsurgical colleagues. Because of this advantage, surgeons were once somewhat contemptuous of laboratory aids and in fact were often skeptical of diagnoses based primarily upon the results of laboratory tests.

The remarkable developments in surgery during the past quarter of a century came about in part as a result of increased interest in physiologic and anatomic changes resulting from disease on the one hand and its surgical treatment on the other.

The surgeon has learned to use the laboratory effectively, and has come to rely upon it as an aid in diagnosis and a guide to both proper preoperative preparation and postoperative management of the surgical patient. The precision with which fluids and electrolytes may be measured and regulated in the patient following operation is a striking example of the importance of physiology. If surgery is to continue to grow and retain its traditional vigor, it must make use of all available tools both for diagnosis and for definition of changes in function. New technics and methods must be carefully evaluated as they appear, for the research methods of today may become practical laboratory aids tomorrow.

This chapter is designed to acquaint the reader with some of the laboratory procedures which may be clinically useful to the surgeon and is intended to supplement the chapters devoted to surgical diseases of individual systems. Routine laboratory tests have not been included and details of the various technics have not been described since these are outside the province of this text.

CARDIOVASCULAR SYSTEM

In no other area are laboratory studies so essential to the correct diagnosis and precise definition of disease as in the field of cardiovascular surgery. Indications for operation and the type of surgical procedure employed must be based upon an accurate knowledge of the cardiovascular condition. As a result of intense interest in this field during the past two decades, a number of tests have emerged from the research laboratory to become useful clinically. These laboratory procedures are described below.

Cardiac Catheterization. Localization of congenital cardiac lesions and measurement of the physiologic alterations produced by both congenital and acquired conditions are dependent upon cardiac catheterization. This procedure consists in passing a small, radiopaque catheter into an arm vein and progressively through the innominate vein, superior vena cava (SVC), right atrium (RA), right ventricle (RV), main pulmonary artery (MPA), right or left pulmonary arterial branch (RPA or LPA), and finally into a distal branch of the pulmonary artery, until

time owes much to systematic follow-up studies in many clinics where patients are examined for months and years at regular intervals after they leave the hospital. In this way only can the end results of surgical procedures be evaluated; for instance, the recurrence rate following herniotomy with various technics is accurately determined only in this manner. Such examinations are not only appreciated by the patients themselves but also serve a useful purpose in the education of students and younger surgeons. Follow-up examinations are especially important in malignant disease in order to determine as early as possible the existence or nonexistence of recurrent growths or metastases.

Oxygen content of right ventricular blood =

$$\frac{110 \times 100}{14.01 - 12.80} = 9.09 \text{ liters per minute}$$

Similar calculations using minute oxygen consumption and oxygen content of mixed venous blood (right atrium) and a systemic artery are employed for estimation of systemic blood flow as follows:

$$\frac{110 \times 100}{14.01 - 8.45} = 1.97 \text{ liters per minute}$$

Subtraction of the systemic from the pulmonary flow gives the amount of blood shunted through the ventricular septal defect per minute.

In a similar manner, right-to-left shunts may be calculated although it is necessary to assume an oxygen content of 96 per cent of capacity for arterial blood since the peripheral arterial blood has a lower oxygen saturation due to mixing at the ventricular level.

Recently, technics have been developed for catheterization of the left heart chambers. At present, the most effective and safest method consists in inserting a No. 17 needle through the anterior wall of the left main bronchus, under bronchoscopic control, into the left atrium. This technic affords information relative to function of the left heart chambers and the mitral and aortic valves.

Angiocardiography. In some instances, clinical examination, routine roentgenography, and cardiac catheterization will disclose the presence of a cardiovascular lesion but its exact location remains in doubt. Under these circumstances, injection of a radiopaque substance into the cardiac chambers, or into the great vessels as they arise from the heart, may provide the desired information. Angiocardiography can be performed by the rapid injection of about 50 ml. of a radiopaque substance (70 per cent Diodrast or Urokon, 50 per cent Hypaque) into an antecubital vein. Serial roentgenograms of the heart and great vessels are made at frequent (one-half to one second) intervals, thus recording the passage of the contrast material through the heart chambers. Recently, biplane roentgenography and cinefluorography have greatly increased the accuracy of angiocardiographic procedures. In both of these procedures the contrast material is injected, usually through a cardiac catheter, into one of the heart chambers. With the biplane technic, roentgenograms are made in two planes simultaneously at a rapid rate; in cinefluorography the movement of the contrast material through the heart and into the great vessels is recorded on motion-picture film at 24 to 64 frames per second.

Arteriography. Although aneurysms about the aortic arch may be satisfactorily visualized by angiocardiographic technics, lesions of the remainder of the aorta and peripheral arteries require injection of the contrast medium directly into the artery. Visualization of the abdominal aorta and its branches is best accomplished by lumbar aortography. This procedure is usually performed under local or light general anesthesia with the patient in a prone position. A special No. 18 needle is inserted beneath the left twelfth rib about 2 to 3 inches from the mid-line and passed medially and upward through the posterior aortic wall. Contrast material is injected rapidly into the aorta and, at the end of the injection, a roentgenogram is made. By properly timing exposure of the film, the celiac, superior mesenteric, and renal arteries above, and the iliac arteries below may be visualized as they arise from the aorta. Visualization of the arteries of the lower extremities may be accomplished at the same time by exposure of a film placed beneath the thighs and knees immediately after exposure of the film beneath the abdomen is completed.

When the arterial disease is confined to the femoral or popliteal arteries, aortography is generally not necessary and femoral arteriograms should be obtained. The technic consists in the retrograde insertion of a No. 18 spinal needle into the femoral artery at the groin under local anesthesia. Contrast material (15 ml. of 35 per cent Urokon or 50 per cent Hypaque) is injected rapidly and a film beneath the thighs and the knees is exposed at the end of or a few seconds after injection.

Blood Volume. The importance of the blood volume has been recognized by surgeons for many years. The vital role of blood volume in the production and correction of traumatic shock and its importance both to the proper preparation of the patient for

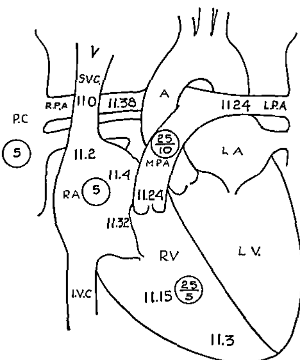


Fig. 1. Diagram of the heart and great vessels showing normal pressures and oxygen contents measured during right heart catheterization. The circled values represent pressure in millimeters of mercury; the uncircled values represent oxygen content in volumes per cent.

the catheter can be passed no farther (pulmonary capillary) (PC) (Fig. 1). Pressures are recorded and blood samples for oxygen content are obtained as the catheter is withdrawn from each of the areas listed. Simultaneously, samples of blood are drawn from a peripheral artery. In addition, minute oxygen consumption is measured. From these data the presence of cardiac shunts may be established (Table 1). The common lesions which permit mixing of blood between the right and left chambers of the heart, or the pulmonary artery and aorta, are atrial and ventricular septal defects and the patent ductus arteriosus. The existence of a left-to-right (noncyanotic) shunt is indicated by the presence of arterialized blood in the atrium, ventricle, or pulmonary artery and a pressure gradient between the systemic and the pulmonary circulation. A right-to-left shunt (cyanotic) is suggested by a significant reduction in peripheral arterial oxygen saturation and equal pressures in the right ventricle and a systemic artery. Frequently, an atrial or ventricular septal defect, or a patent ductus arteriosus, may be demonstrated by passing the cardiac catheter through the abnormal aperture.

Of equal importance with the detection of these congenital conditions are the physiologic alterations resulting from their presence. Measurement of the amount of blood flowing through the shunt may be determined from the arteriovenous oxygen difference and minute oxygen consumption. Thus, the quantity of blood passing through a ventricular septal defect is calculated as follows:

Minute oxygen consumption = 110 ml. per minute
Oxygen content of arterial blood = 14.01 volumes per cent

TABLE 1. Data Obtained at Right Heart Catheterization in Normal Subject and in Patients with Atrial Septal Defect, Ventricular Septal Defect, The Tetralogy of Fallot, and Patent Ductus Arteriosus.

Source	Normal Subject		Atrial Septal Defect		Ventricular Septal Defect		Tetralogy of Fallot		Patent Ductus Arteriosus	
	Blood O_2 Content Vol. %	Pressure mm. Hg.	Blood O_2 Contents Vol. %	Pressure mm. Hg.	Blood O_2 Content Vol. %	Pressure mm. Hg.	Blood O_2 Content Vol. %	Pressure mm. Hg.	Blood O_2 Content Vol. %	Pressure mm. Hg.
SVC	11.5	4	10.6	9	14.1	10	11.0	10	9.9	8
RA	11.81	4	15.1	9	14.1	10	11.0	10	9.8	8
RV	11.3	17/4	14.7	36/9	16.5	64–48/10	11.0 (low) 12 0 (high)	104/10 20	9 6	38/8
MPA	11.1	17/7	14.9	33/18	16.3	48/18	12.0	20/10	12.9	38/16
RPA	11.2	17/7	14.8	32.8/17.6	16.4	48/18	12.0	20/10	12.9	18
PC		12		10		20				
Brachial Artery	15.2	84/52	15.9	132/92	18.4	120/60	14.8	104/70	14.8	120/50
Hemoglobin	12.4 gm.		12.6 gm.		15.0 gm.		13.0 gm.		15.5 gm.	
Pulmonary Flow	5.6 L/min.		12.0 L/min.		11.2 L/min.		4.0 L/min.		12.0 L/min.	
Systemic Flow	5.6 L/min.		2.4 L/min.		5.4 L/min.		5.32 L/min.		6 0 L/min	

as a result of conditions affecting the air passages or *restrictive* as a result of conditions involving the chest bellows or distensibility of the lungs. There are three measurements of ventilatory function commonly employed: The *timed vital capacity* consists in recording the maximal speed of performance of a vital capacity expiration. This is perhaps the simplest method of measuring maximum ventilatory performance. The *maximum breathing capacity*, as generally performed, consists in measurement of the maximum, voluntary, minute ventilation. For this test the patient selects his own rate and depth of breathing and this maximum voluntary effort is recorded on a spirometer for either 15 or 30 seconds. *Breathing reserve* is the difference between ventilation at ordinary levels and the maximum breathing capacity. This should represent about 65 to 70 per cent of the maximum breathing capacity; below this level dyspnea is usually evident (Table 3).

Respiratory Gas Exchange. For clinical purposes, studies of lung volumes and ventilatory functions are generally adequate to assess pulmonary function. The phenomena related to the exchange of gas within the lung are exceedingly complex, and, for this reason, studies of these functions have been confined to the research laboratory *until recently*. However, relatively simple methods are available now for clinical study. These include:

1. Measurement—at rest and during exercise—of ventilation, carbon dioxide output and oxygen uptake, oxygen saturation, and carbon dioxide tension in the arterial blood. From these determinations diffusion of gases across the alveolar-capillary membrane may be assessed.

2. The extent to which gases mix in the lung may also be measured by determining the amount of nitrogen in the expired air after the subject has breathed pure oxygen.

Differential Studies. In evaluating thoracic surgical patients with limited pulmonary reserve, it may be necessary to know how total pulmonary function is distributed between the two lungs. For this purpose differential bronchospirometry is useful. This procedure consists in inserting a catheter into the right main bronchus. A balloon is inflated to occlude the right bronchus, thus separating the left lung from the right. By this technic, ventilation, vital capacity, and oxygen consumption of each lung can be measured separately and the functional contribution of each lung expressed as a percentage of the total.

It must be kept in mind that pulmonary function tests are most useful when evaluated in terms of clinical manifestations and roentgenographic studies. Nor do they necessarily indicate or contraindicate the need for operation. Rather, they constitute additional evidence upon which the surgeon can base his decisions regarding treatment.

GENERAL METABOLIC

The problems of water, electrolyte, and acid-base balance are legion in clinical medicine and it is not within the scope of this section to describe the various related laboratory tests and their interpretation in other than a most limited manner. Patients with abnormal intake and output of water and electrolytes as well as those with such internal

TABLE 3. Predicted Normal Values for Vital Capacity and Maximum Breathing Capacity.

Measurement	Predicted Values
Vital capacity, supine, ml.:	
Males	27.63—(0.112 × age in years) × height in centimeters
Females	21.78—(0.101 × age in years) × height in centimeters
Maximum breathing capacity, standing, liters per min:	
Males	86.5 —(0.522 × age in years) × body surface in square meters
Females	71.3 —(0.474 × age in years) × body surface in square meters
Timed vital capacity (males and females):	
First second	83 % of vital capacity
Second second	94 % of vital capacity
Third second	97 % of vital capacity

TABLE 2. Blood Volumes in Normal Male and Female Subjects (Berlin).

Subjects	No. of Cases	Blood Volume ml./kg.	Total Red Cell Volume ml./kg.	Plasma Volume ml./kg.	Hematocrit Per Cent
Males	71	69.0	29.9	38.7	43.0
Females	16	64.4	27.0	37.0	42.0

operation and to convalescence are now well understood. Generally, the experienced surgeon will recognize acute blood volume deficits by the clinical manifestations of tachycardia, hypotension, pallor, and sensitivity to postural change. However, following operations in which blood loss and blood replacement have been extensive it is difficult if not impossible to estimate accurately the status of the blood volume by clinical signs alone. This is particularly true after operations for massive gastrointestinal hemorrhage and after certain thoracic and cardiovascular procedures. Under these and other circumstances measurement of blood volume is desirable (Table 2).

This is accomplished by injecting intravenously a known quantity of a substance which remains essentially within the plasma, allowing it to mix homogenously, and then determining the quantity of this material in the plasma. Three substances are commonly employed for this purpose: T-1824 or Evans Blue Dye, human serum albumin labeled with radioiodine, and erythrocytes labeled with chromium, phosphorus, or iron. When T-1824 or iodoalbumin is used, the total plasma volume is measured and from the hematocrit value the total blood volume is determined. If labeled erythrocytes are employed, the red cell volume is measured and the total volume is then derived from the hematocrit value.

RESPIRATORY SYSTEM

Evaluation of pulmonary function is necessary for any patient undergoing a thoracic surgical procedure and for patients with pulmonary disease, irrespective of the type of operation contemplated. In most instances, a careful history and physical examination, together with a comparison of ventilatory effort at rest and at exercise, will be sufficient. On the other hand, some patients, particularly those with questionable pulmonary reserve, must be studied more thoroughly. Under these circumstances the following measurements of pulmonary function will be useful.

Lung Volumes. There are four components of lung volume which may be measured separately. *Tidal volume* is the volume of gas displaced with each breath. *Inspiratory reserve volume* is the volume of gas that can be inhaled by a maximum inspiratory effort after the inspiratory limits of the tidal volume has been reached. *Expiratory reserve volume* is the volume of gas that can be exhaled by maximum expiratory effort after the expiratory limit of the tidal volume has been reached. *Residual volume* represents the volume of gas remaining after forceful expiration. The sum of these four measurements represents total lung capacity (Fig. 2).

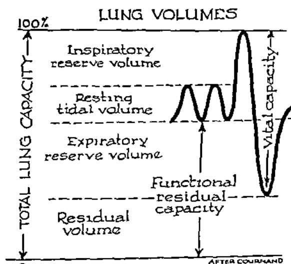


Fig. 2. Normal spirogram showing the various components of lung volume.

Ventilatory Function. The measurement of lung volumes is helpful in evaluating the functional effects of abnormalities of the lungs, while the ventilatory tests assess the functional capacity of the thoracic bellows or the distensibility of the pulmonary parenchyma and the patency of the air passages. Ventilatory dysfunction may be *obstructive*

after 15- or 30-minute intervals. Other methods of gastric stimulation may be used, such as the Ewald or Boas test meal. Another type of test meal is the use of 100 ml. of 7 per cent alcohol injected through the tube. Specimens are taken 30 minutes and one hour after test meals. The most informative type of gastric acidity curve is obtained when the samples are taken at 15-minute intervals for two hours. Maximum stimulation of gastric secretion, which may be obtained with administration of insulin, is useful in evaluating the completeness of vagotomy. An appropriate dose of insulin (10 to 20 units) is given intravenously to produce hypoglycemia of 50 mg. per cent or less. Gastric samples are collected at 15-minute intervals for two hours and blood samples are taken at 30-minute intervals to determine if a satisfactory hypoglycemia has been obtained. The effect of hypoglycemia is mediated through the vagus center in the midbrain and through the vagus nerve. The production of free hydrochloric acid in the stomach, in response to hypoglycemia, depends on the normal reflex arc, midbrain, vagus nerve, and stomach glands. Complete interruption of the vagus nerve will prevent the secretion of free acid. However, the acid-secreting glands still will respond to histamine or caffeine stimulation following vagotomy.

A number of valuable observations may be made from the examination of gastric fluid. The volume of the fasting specimen usually varies between 30 and 60 ml. The presence of more than 100 ml. of gastric juice is usually considered to be evidence of pyloric obstruction. The color of the fluid may denote the presence of bile, which indicates that the patient does not have a complete pyloric obstruction. The presence of blood, confirmed by guaiac or benzidine tests, suggests the possibility of ulcer, carcinoma, or gastritis. Food particles in the fasting specimen suggest obstruction and, if identified and related to time of ingestion, the specific period of stasis can be recorded. Other observations such as the odor and the presence of mucus or saliva should also be noted. Microscopic examination of the residue from a fasting stomach may reveal various types of food particles, blood or pus cells, or various types of bacteria. Occasionally seen are the Boas-Oppler bacilli which are very large gram-negative, non-spore-bearing organisms. Growing in chains and masses they produce lactic acid, and may be cultivated on media in rich milk or in blood. The Boas-Oppler bacilli in the absence of hydrochloric acid and in the presence of stasis may accompany gastric cancer. Sarcinae may occur with stasis in the presence of hydrochloric acid and suggest pyloric obstruction. Occasionally parasites may be found.

The presence of free HCl and total acid in the gastric secretion is important. Usually these observations are made on quantitative bases and expressed in degrees of acidity, the degrees indicated in the number of milliliters of tenth normal sodium hydroxide required to neutralize 100 ml. of gastric content. The total acid represents the free acid, HCl combined with protein, plus acid salts and organic acids. There is a wide variation in the amount of free and total acid found in the stomach of a normal individual. In a normal adult this may vary from 0 to 30 units of free acid and from 5 to 40 units of total acid. Total anacidity is uncommon in young adults but increases with age so that about 30 per cent of males and about 20 per cent of females in the sixth decade have an anacidity. Normal acidity curves following a test meal, as well as those in patients with hypoacidity and hyperacidity, are shown in Figure 4. In general, patients with duodenal ulcer have increased volume and acidity. The presence of achlorhydria with gastric ulcer suggests that the lesion must be regarded as malignant until proven otherwise. Achlorhydria usually accompanies a diagnosis of pernicious anemia and occurs also with idiopathic hypochromic anemia.

It is frequently possible to identify *Mycobacterium tuberculosis* by recovering swallowed sputum from the gastric content when it is not possible to obtain sputum otherwise. A fasting specimen is obtained and the concentrate may be smeared and studied microscopically for acid-fast bacilli or injected in the guinea pig as a biological test for tuberculosis.

Gastric carcinoma may be diagnosed by cytologic technics utilizing recovered samples of gastric content. A normal washing may be

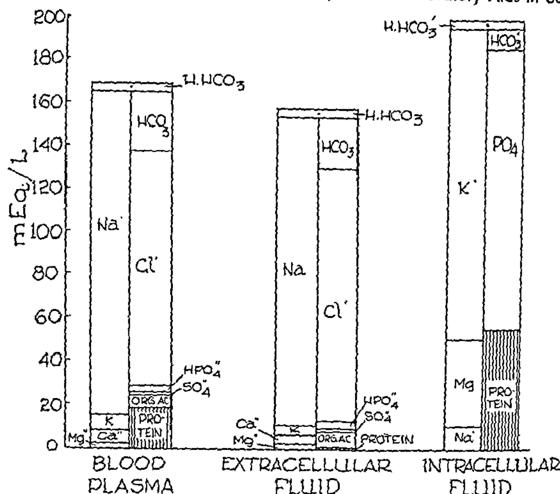


Fig. 3. The chemical composition of intracellular fluid, extracellular fluid, and blood plasma of man. (Adapted from Gamble.)

derangements as fistulas, hemorrhage, or draining wounds require careful evaluation and exact knowledge of the chemical composition of the extracellular fluid. Observations should be made on the patient of body weight, fluid intake and output, the specific gravity of the urine, and the blood count—including the hematocrit.

The volumes of the various compartments of body fluid can also be determined by special examinations. Methods are available to measure the red cell volume, plasma volume, the extracellular fluid, and the total body water. The serum electrolytes usually obtained are sodium, potassium, chloride, calcium, and magnesium; normal values are listed in Table 4. The chemical compositions of the intracellular fluid, the extracellular fluid, and the blood plasma are depicted in Figure 3.

TABLE 4. Normal Values of Serum Electrolytes.

	mEq/L	mg. %
Sodium	135.0–147.0	310.0–340.0
Potassium	3.5–5.5	18.0–22.0
Calcium	4.5–5.5	9.0–11.0
Magnesium	1.5–3.0	1.8–3.6
Carbon Dioxide (combining power)	25.0–30.0	56.0–65.0
Chlorides	100.0–110.0	350.0–390.0

GASTROINTESTINAL

Stomach. Gastric analysis is a commonly available test for the study of gastric physiology. An early morning fasting specimen is obtained through a nasogastric tube by the routine technic. If no free acid is present, as determined by the addition of Topfer's reagent, the patient is given a gastric stimulant such as caffeine sodium benzoate or histamine. Subsequent specimens are removed

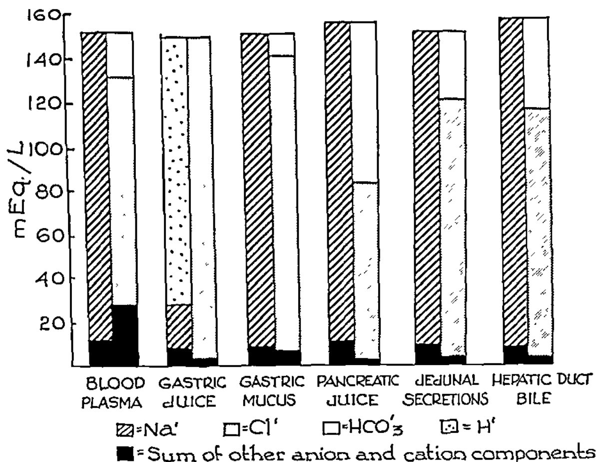


Fig. 5. Composition of intestinal fluids. (Adapted from Gamble.)

greatest value as a screening test for achlorhydria. When used for quantitative determination of the HCl in the stomach this method has not proven reliable. It is useful in determining the presence of acid in patients with active gastric bleeding in whom intubation is contraindicated or in those patients with severe angina or coronary infarction.

Duodenum. It is sometimes helpful to obtain duodenal drainage through an appropriate nasogastric tube, the position of which needs to be checked by fluoroscopy, although the presence of fluid with an alkaline pH strongly suggests that the tube has entered the duodenum. Injection of a 33 per cent magnesium sulfate solution through the tube will cause relaxation of the sphincter of Oddi and it may be possible to obtain gall bladder bile which is generally dark. This gradually becomes lighter and represents yellow or hepatic bile. Certain observations may be significant in examination of this aspirant, such as the presence of sand from the biliary tree, pus cells, bacteria (particularly typhoid bacilli), *Giardia lamblia*, or *Endamoeba histolytica.*

Chemical determinations may be made on intestinal fluids particularly at different levels of the bowel to determine the electrolyte composition of gastrointestinal secretions (Fig. 5). It is important to be aware of the composition of the intestinal fluids as loss through external fistulas or by vomiting or diarrhea must be replaced with a similar electrolyte solution to avoid serious depletions.

In addition to the direct examination of the duodenal drainage, useful information may be obtained by performing a secretin test consisting of the injection of one unit of secretin per kg. body weight intravenously, after a control specimen of duodenal contents has been obtained. The secretin causes a flow of pancreatic juice which is collected at 20-minute periods for the next 80 minutes. Gen-

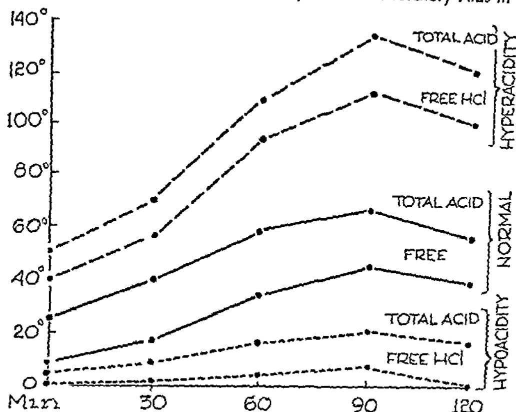


Fig. 4. The gastric acidity curve after test meal in patients with normal acidity, hyperacidity, and hypoacidity.

recovered, concentrated, smeared, and examined by the Papanicolaou technic.

Refined technics have been utilized whereby a solution of papain or trypsin is introduced into the stomach to dissolve the mucus covering the gastric mucosa and the malignant lesion, thus making a recovery of tumor cells less difficult. Another technic is the "brush" biopsy method, which consists of a small brushlike implement attached to a gastric tube that is passed into the stomach and entangles malignant cells in its fibers. When the tube has been removed the cancer cells can be recovered, smeared, and identified by cytologic technics. Another similar method utilizes an abrasive balloon attached to a gastric tube as described by Ayers.

In addition to the standard gastric analysis described above, there is a method of determining gastric achlorhydria described by Segal and Morton in 1950 using ion exchange resins (quinine carbacrylic resin). These authors demonstrated that the hydrogen ions of gastric juice below pH 3 displaced the quinine cation and this cation was excreted in the urine. The compound was administered orally in a fasting patient and urine was analyzed for the presence of quinine in a two-hour specimen. This test has been refined and various cation indicators substituted. Probably the most reliable indicator has been a carboxylic cation exchange resin containing Azure A dye as the indicator ion, administered by mouth to the fasting patient. The urine specimen is obtained after two hours, and the amount of dye in the urine is measured with a spectrophotometer at an optimum pH. With this technic, 0.6 mg. of dye must be excreted if free acid is present in the gastric juice. Most investigators have recommended the use of histamine or caffeine sodium benzoate to stimulate gastric secretion in conjunction with the resin. There is a 7 to 10 per cent error in patients who are known acid secretors and give false negative results with the test. In individuals with pyloric obstruction, malabsorption from the intestine, severe disease of liver or kidney, or with urinary retention, the test is not indicated. Most individuals report that in pernicious anemia or gastric carcinoma the absence of free acid in the stomach is confirmed. Perhaps this technic has the

creased to 60 or 80 per cent and is largely neutral fat. In obstructive jaundice, sprue, or conditions where absorption is disturbed, there is an excess of total fat in the feces, but this usually consists of fatty acids since the pancreatic lipase is not reduced in these conditions.

Liver. The multitude of metabolic activities occurring in the liver has resulted in development of numerous tests to evaluate the function of this organ in health and in disease. These tests may be utilized as follows: 1. elucidate liver physiology; 2. offer prognosis in established disease; 3. evaluate the results of therapy; 4. aid in the selection of operative or nonoperative therapy in a jaundice patient; and 5. detect subclinical liver disease. The liver has a tremendous reserve so that only 15 to 20 per cent of the liver parenchyma is necessary to sustain life. This large safety factor works to the disadvantage of the physician as significant areas of the liver must be involved before impairment of function is manifested by the various liver studies. In addition, most functions of the liver occur in histologically similar polygonal cells and these cells may perform some functions well and yet be defective in the performance of others so that a battery of tests is necessary for evaluation of liver function. A description of the more useful tests will follow; see Table 5 for normal values.

TABLE 5. Normal Values of Liver Function Tests.

Test	Normal value
Icteric index	4–7 units
Bilirubin, direct (immediate)	0.1–0.2 mg.%
Bilirubin, indirect (total)	0.2–1.0 mg.%
Serum proteins	
Albumin	3.5–5.5 gms.%
Globulin	1.5–3.4 gms.%
Fibrinogen	200–600 mgs.%
A/G ratio	1.6–2.0
Cholesterol, total	110–300 mgs.%
Prothrombin time	70–110% of control
Phosphatase, alkaline	3–5 units (Bodansky)
Cephalin flocculation	0–1+
Thymol turbidity	0–5 units
Zinc sulfate turbidity	5–14 units
Transaminase	10–40 units
Bromsulphalein (5 mg./kg.)	5% of dye or less in serum at 45 minutes.

The simplest estimation of the bilirubin content in the plasma is by the icteric index, which is obtained by matching the color of plasma or serum with dilutions of a standard solution of potassium dichromate. Normal values are between 4 and 7 units. The first detectable clinical jaundice occurs at 15 units. This is not a specific test as hemolysis of red cells, various drugs such as atabrine or dinitrophenol, or carotenemia may give a yellow color to the serum. The main value of the test is as a screening procedure and to follow the level of jaundice in patients under observation and treatment.

Hemoglobin is broken down in the reticuloendothelial system forming free bilirubin. This is indirect bilirubin which is fully soluble in water at the physiologic pH and is not excreted by the kidney. Indirect bilirubin, normally present in serum in concentrations of less than 1 mg. per cent, is conjugated in the parenchymal cells of the liver with glucuronic acid and forms bilirubin glucuronide. This is a water-soluble complex which gives a direct reaction with Ehrlich's diazo reagent. The maximum normal concentration in serum is 0.2 mg. per cent. Excesses beyond the normal maximum appear in the urine. The bilirubin glucuronide is excreted into the bowel via the common bile duct where, by the action of the intestinal flora, it is converted into a group of colorless chromogens which are called urobilinogen. The urobilinogen will react with Ehrlich's aldehyde reagent and is the basis for identifying urobilinogen in the stool. The urobilinogen produced in the intestine is then oxidized to urobilin which produces the orange-brown, normal color of feces. The oxidized form must be demonstrated by the Schlesinger test.

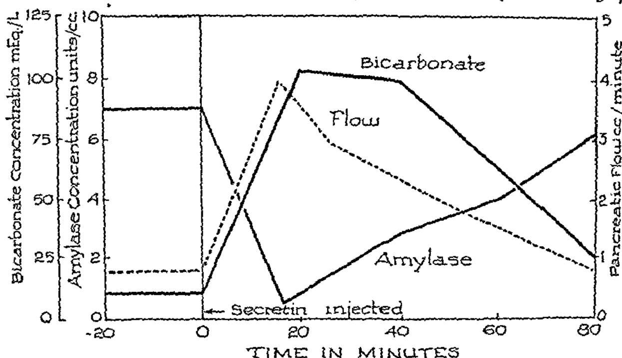


Fig. 6. Normal response in the secretin test. (Adapted from Dreiling.)

erally the drainage is examined for volume, bicarbonate concentration, amylase concentration, guaiac reaction, icterus index, and cellular elements. The first three observations characterize the pancreatic response to the secretin. In normal individuals there is a rapid increase in the rate of pancreatic secretion which quickly reaches a maximum and subsides at the end of 80 minutes. Normal individuals will secrete from 100 to 300 ml. during this period. Obstruction of the pancreatic ducts will cause a reduction of the flow. The bicarbonate concentration follows the volume but responds more slowly and lasts somewhat longer. The amylase concentration usually varies inversely with the pancreatic flow. The normal quantity of amylase produced over a period of 80 minutes equals six or more units per kilogram. Thus, patients with pancreatic tumors usually show a reduction in volume, while patients with extensive lesions that have destroyed significant portions of the secreting parenchyma may show some diminution of potency of the secretion. In acute pancreatitis this test is of little value; however, in chronic pancreatitis the volume tends to remain normal, but there is a marked lowering of the maximum bicarbonate concentration. Enzyme secretion is usually less affected. Figure 6 indicates the normal response to the injection of secretin.

Colon. The stool examination is the routine laboratory test conducted on feces. The presence of blood in the stool is of clinical significance and it is important to note whether this is bright blood presumably coming from the anus or rectum or dark blood coming from higher in the colon or terminal small bowel. If the stool is actually tarry in color this indicates the presence of blood from the upper gastrointestinal tract. In addition to the gross and microscopic examination of the stool, cultures may be obtained to identify various members of the typhoid-dysentery group. These cultures should be made on special media. The stool may be examined for urobilin, or urobilinogen which is referred to under the section on the liver. Occult blood is determined by the guaiac test and is usually a sign of an ulcerated lesion in the colon or small bowel.

It may be important to determine the quantity of fat in the stool and the proportion comprised of neutral fat and fatty acids. Normally, total fat in the stool is from 15 to 25 per cent by weight, neutral fat from 1 to 2 per cent, and fatty acids 9 to 13 per cent. In pancreatic insufficiency the total fat may be in-

mal values will be obtained. The test is normal early in infectious hepatitis but rises quickly to levels of 15 to 25 units.

The transaminase test is a measurement of the glutamic-oxalacetic transaminase which is an enzyme widely distributed in tissues, occurring in greatest concentration in heart muscle, skeletal muscle, brain, liver, and kidney, in decreasing order. Cellular destruction, such as that caused by acute myocardial infarction, liver-cell destruction, or damage to skeletal muscle, all produce marked elevation in the transaminase blood level. The following observations of transaminase levels in liver disease have been reported by Wroblewski and LaDue.

Carbon tetrachloride liver damage has produced elevations to 27,840 units.

Patients with infectious hepatitis or homologous serum jaundice have elevations of the transaminase level.

The serum transaminase is a relatively sensitive index of liver metastases except when there is involvement of the liver with lymphoma or leukemia.

Elevations occur in cirrhosis but are not constant and apparently reflect superimposed hepatitis.

Extrahepatic obstructive jaundice is accompanied by minimal elevation of the serum transaminase which responds to surgical correction of the obstruction.

Elevation of the alkaline phosphatase resulting from bone disease may be differentiated from that resulting from liver disease by the fact that the transaminase is not increased in the former.

The transaminase activity in the presence of liver disease does not necessarily correlate with the liver function tests in common use but does indicate liver cell destruction.

The liver synthesizes prothrombin from fat-soluble vitamin K, hence the determination of the prothrombin can be used as a test of liver function. The normal prothrombin time is from 70 to 100 per cent of the control. The test is not particularly sensitive in patients with lesser degrees of liver damage from hepatitis or intermittent obstruction. With obstructive disease, the lack of bile in the bowel will interfere with proper absorption of vitamin K. When the prothrombin time is lowered, 1 mg. of vitamin K can be given intravenously and the determination repeated in 24 hours. The patient with early obstructive jaundice or mild infectious hepatitis will have a rapid response to the vitamin K with a return to normal prothrombin time. If the prothrombin time does not respond promptly to vitamin K, this is an indication of severe liver damage.

The total serum protein, which normally runs from 6 to 8 gm. per cent, as well as the fractional proteins—specifically albumin, globulin, and fibrinogen—may be used as tests of liver function, as these proteins are synthesized in the liver from amino acids. The normal albumin level is 3.5 to 5.5 gm. per cent; globulin, 1.5 to 3.4 gm. per cent; and fibrinogen, 200 to 600 ml. per cent. Lowered levels or reversal of the albumin-globulin ratio, which normally is 1.2 to 2 usually, results from impaired liver function.

Serum cholesterol may be affected by liver disease; the normal cholesterol varies from 110 to 300 mg. per cent. Hypercholesterolemia usually accompanies early jaundice due to common duct obstruction.

Pancreas. The pathophysiology of the pancreas lends itself to study by various laboratory aids. Reference has been made heretofore to the secretions emptied into the duodenum and to the secretin test.

The serum levels of the various enzymes produced by the pancreas are utilized to indicate evidence of impaired function. The three major enzymes are amylase, lipase, and trypsin. Standard determinations of the first two are available. The normal serum amylase is determined by the digestion of a starch solution by the amylase in a specific amount of serum. The remaining starch reacts with iodine and the resulting color is read on a colorimeter. Normal levels are expressed in Somogyi units and range from 80 to 150.

The serum lipase test utilizes the liberation of tributeric acid from aqueous tributyrin by serum lipase. The liberated acid is titrated with standard sodium hydroxide. Normal levels range from 0.5 to 1.5 units (N/20 NaOH).

Only recently, a test to determine serum trypsin, has been described by Nardi and Lees. A polypeptide substrate with an amide linkage, vulnerable only to trypsin, has been synthesized. The digestion of the substrate is

Small amounts of the urobilinogen are reabsorbed from the intestine into the portal circulation, some is excreted by the liver and some by the urine. This may be identified by the use of Ehrlich's aldehyde reagent. The excretion of urobilinogen is one of the more sensitive functions of the liver and is reduced early in the course of parenchymal disease. This condition will cause an increase in the amount of urobilinogen in the urine. Hemolytic jaundice brings about an increase in the amount of bilirubin excreted in the intestine and results in an increase in urobilinogen content in both urine and stool. With biliary tract obstruction, the feces become clay colored and urobilinogen does not appear in either urine or stool since the bilirubin cannot reach the intestine.

The bromsulphalein test is widely employed as a liver function test. The reticuloendothelial cells of the liver excrete bromsulphalein into the bile; a decreased rate of excretion is evidence of liver damage. This test should not be performed when the patient is jaundiced or if a phenolsulfonphtholein (PSP) test has been performed recently. Five milligrams per kilogram of the dye are injected intravenously in the fasting patient. Blood is drawn, usually at 30 and 45 minutes, and serum is obtained, alkalinized, and compared with normal color standards. In the normal individual, 5 per cent or less of the dye remains in the serum at 45 minutes.

There are a number of other tolerance tests, less frequently performed, that determine the ability of the liver to detoxify or secrete substances injected intravenously or taken by mouth. The test agent or conjugant remaining in the blood or excreted in urine after being acted upon by the liver is used to measure hepatic function. The following tests utilizing these principles are listed for reference: fructose tolerance; galactose tolerance; hippuric acid test; lactic acid test; and rose bengal test.

The cephalin-cholesterol flocculation test of Hanger is a sensitive indicator of parenchymal liver cell damage and is simple to perform, dependable, and readily available. An emulsion of cephalin, made from sheep brain, and cholesterol is prepared. The addition of serum will cause a flocculation which is expressed in terms of 0 to 4+. The mechanism apparently is related to changes in the serum globulin. The test is strongly positive in hepatitis and is usually negative in early obstructive jaundice. A positive test in obstructive jaundice will occur as the parenchymal cells undergo damage from prolonged obstruction.

The thymol turbidity test of Maclagan also gives a good indication of hepatic parenchymal damage. The patient's serum is added to serially diluted solutions of thymol barbital and the degree of turbidity is read on a spectrophotometer. The normal values range from 0 to 5 units. This mechanism is not definitely understood but apparently the turbidity is produced in the thymol buffer by the interaction of gamma globulin and a lipoprotein component of the serum. The test rapidly becomes positive in infectious hepatitis and is useful when following the course of the disease. Patients with obstructive jaundice usually show normal values. Increase in the total serum lipids may produce some degree of thymol turbidity. This fact must be remembered in obstructive jaundice as there may be some elevation in the lipid level.

The serum alkaline phosphatase is useful in the study of obstructive liver disease and the normal level in serum is from 3 to 5 Bodansky units in adults and somewhat higher levels in children. In cases of obstructive biliary tract disease, 90 per cent of the patients have elevated levels of more than 10 Bodansky units. In patients with infectious hepatitis or hemolytic jaundice, the reverse is true. The alkaline phosphatase may also be elevated in certain bone diseases, in parathyroid disfunction, and in cholangiolytic hepatitis. In patients with normal or nearly normal serum bilirubin, elevation of the alkaline phosphatase occurs with chronic infiltrating diseases of the liver due to sarcoid, tuberculosis, Hodgkin's disease, and similar conditions.

The zinc sulfate turbidity test described by Kunkel is a simple method for the quantitative estimation of serum gamma globulin and is useful in differentiating between obstructive and nonobstructive jaundice. Normal values range from 5 to 14 units. Elevated levels may be found in many diseases in which there is an increase in serum gamma globulin. In patients with uncomplicated obstructive jaundice nor-

phthalein excreted is a relative index of the functioning tubular tissue. On the other hand, such factors as diminished blood flow to the kidney, delayed absorption when the drug is given intramuscularly, and certain types of liver disease may significantly alter the amount of phenolsulfonphthalein excreted in the presence of normal renal function. Nevertheless, if the test is properly performed and evaluated it may be extremely useful. The dye is injected intravenously, and the urine is then collected for two hours. Normally, at least 70 per cent of the dye injected is excreted within this period. The best results are obtained if the patient is hydrated before the test in order to increase the urinary output.

CLEARANCE STUDIES. A more exact definition of the discrete functions of the kidney requires the use of clearance technics (Table 6). With the exception of urea clearance, these technics have been employed primarily as research methods. Recent experience, however, indicates that discrete renal function tests may have prognostic significance, particularly following surgical procedures which interfere temporarily with renal blood flow (Table 7). For this reason these tests are described here briefly.

TABLE 7. Data Relating to Discrete Renal Function Studies in a Patient with a Thoracoabdominal Aortic Aneurysm.
(Resection required temporary interruption of the renal arteries. Recovery of renal function was evident by the third week after operation.)

DETERMINATION	BEFORE OPERATION	DAYS AFTER OPERATION 2	7	22
Glomerular Filtration Rate ml./min.	67	19	44	59
Renal Plasma Flow ml./min.	277	121	226	358
Renal Blood Flow ml./min.	461	212	396	596

The determination of urea clearance is perhaps the most useful test of renal function. Urea is a freely diffusible substance, but a small part of the urea is reabsorbed by the tubules and does not appear in the urine. For best results, the urea clearance should be performed when urine flow is above 2 ml. per minute so that the clearance is "maximal." When the urine output is less than 2 ml. per minute the clearance of urea diminishes in proportion to the square root of the urine flow. Using this relationship the "standard" clearance may be determined. Although the normal variation is large, the average maximal clearance for a normal adult is about 75 ml. per minute and the standard clearance is 54 ml. per minute. A reduction below 75 per cent of normal must occur, however, before the clearance can be considered definitely abnormal.

Specialized clearance studies are less useful clinically because they are more difficult to perform yet they are more accurate and specific than the renal function tests described above. For performance of these clearance studies, three variables must be measured as follows: 1. concentration of a solute in the urine, U; 2. quantity of of urine excreted during a unit of time, V; and 3. the simultaneous concentration of this substance in the plasma, P. Clearance of the solute is derived from the ratio UV/P and represents the smallest quantity of plasma from which the solute excreted in the urine could be obtained during unit time. This formula is similar to one used in determining urea clearance, but the difference lies in the fact that urea is partially reabsorbed in the tubules, whereas the substances employed in other clearance studies are completely filtered in the glomerulus; thus the *glomerular filtration rate* may be measured with such a solute as inulin, mannitol, or thiosulfate which is completely filtered in the glomerulus and is unchanged in the tubules. The ability of the glomeruli to remove a solute from the plasma in unit time can be determined accurately with this test.

Tubular reabsorption and secretion can be estimated by simultaneously measuring the rate of excretion of a urinary constituent and the glomerular filtration rate of inulin. Paraaminohippurate and Diodrast are actively secreted by the tubules when infused at a slow rate. Portions of these substances are bound to protein and only partially filtered. The remainder is secreted at a rate approaching

measured, thus enabling a quantitative estimation of the trypsin in the patient's serum. Normal individuals have little or no circulating trypsin present.

It is also possible to obtain indirect measurement of the circulatory enzymes by determining the antienzyme levels. A system containing an appropriate substrate and the specific enzyme is set up. The rate of digestion of the substrate can be determined and compared with a test system to which the patient's serum has been added. The per cent digestion as compared to the normal may be determined.

These tests are very sensitive to many pathological situations and are not used commonly owing to the lack of specificity.

Blood sugar levels are controlled by insulin secreted in the pancreas by the islands of Langerhans. The normal fasting level ranges from 80 to 120 mg. per cent. Diabetes mellitus is the disease of major importance that causes elevation of the blood sugar. With elevation of the glucose level, sugar appears in the urine where it can be detected by the Benedict test. The presence of ketone bodies such as acetone, diacetic and beta-hydroxybutyric acid may also be detected by appropriate urinalysis. There are many causes for elevation of the blood sugar and the appearance of sugar in the urine. A glucose tolerance test will help to clarify the cause of an elevated fasting blood sugar. Standard references are readily available for interpretation of abnormalities of glucose metabolism.

RENAL EXCRETORY SYSTEM

Routine analysis of the urine for the presence of protein, sugar, acetone, and formed elements should be performed in every case. In addition, determination of the amount and type of urine formed is also important. Measurement of the total daily urinary output together with extrarenal fluid losses, and comparison of these with fluid intake is the most practical measure of renal function in the surgical patient and provides a therapeutic guide as well. When more precise evaluation of kidney function is desirable, determination of urine and plasma solutes is indicated. This includes measurement of urea, creatinine, sodium, chloride, potassium, and the carbon dioxide combining power of the blood, and simultaneous determinations of sodium, chloride, and potassium in the urine.

In many instances it is essential to determine the ability of the kidneys to respond to water deprivation and to water excess. These tests measure the concentrating function of the kidneys and are usually performed by placing the patient on solid food, without fluid, for a twelve-hour period, followed by a similar period of high water intake. Normally the stimulus of restricted water results in an increase in specific gravity of the urine to a level of 1.025 to 1.030, the intake of excess water results in a fall to 1.003. The elaboration of urine of a fixed specific gravity is commonly seen in certain renal diseases. Under these circumstances the specific gravity of the urine is usually about 1.010 to 1.012; in other words, that of the glomerular filtrate.

The phenolsulfonphthalein excretion test is one of the most commonly used for estimation of renal function (Table 6). This substance is a dye which is excreted by the renal tubules. After injection, most of the dye combines with serum albumin, thus cannot pass the glomerular membrane, and is excreted by the tubules. The amount of phenolsulfon-

TABLE 6. Normal Values for Tests of Renal Function

Concentration and dilution: specific gravity of urine;
- After dry day 1.025 or more
- After water day 1.003 or less

Phenolsulfonphthalein:
- Intramuscular injection: 55–75% in urine in 2 hours
- Intravenous injection: 25% or more in urine in 15 minutes

Urea Clearance:
- 40 ml. or more blood cleared per minute. Variations of 75–125% of average normal

Renal Clearance (corrected to 1.73 square meters body surface area):
- Inulin clearance (C_I) (measure of glomerular filtration rate)
  - Males 124.1 ± 25.8 ml./min.
  - Females 119.0 ± 12.8 ml./min.
- Para-aminohippuric acid (C_{PAH}) (measure of effective renal plasma flow)
  - Males 654.0 ± 163.0 ml./min.
  - Females 594.0 ± 102.0 ml./min.
- Tubular maximum for PAH
  - Males 77.2 mg./min.
  - Females 77.2 mg./min.

mal values are 4 to 8 μg. per cent which are constant for men, women, and children. Occasionally, observations of 3 to 9 μg. per cent are seen in normal patients. Sources of error may be found in the use of syringes or collection bottles contaminated with iodine, or when preparation of the patient's skin for needle puncture is performed with tincture of iodine. In addition, the patient must not have had any iodine therapy (as Lugol's solution, cough medicine, or throat lozenges containing iodine) for three to four weeks prior to the test. The patient must not have had cholecystography, pyelography, or other diagnostic x-ray procedures employing organic iodine compounds such as priodax and lipiodol. These iodine compounds will cause interference and abnormally high determinations from three to six months after their use. Interference has been caused by intrathecal Lipiodol for as long as three years, and by organic iodine treatments for parasitic infections. Diuretic mercurial compounds produce erroneously low levels for short intervals by interfering with the chemical determination of iodine.

Normal serum cholesterol varies from 110 to 300 mg. per cent. Cholesterol is classified as a body lipid along with neutral fat, fatty acids, and phosphatids, of which it normally constitutes 20 to 40 per cent. Chemically it is an alcohol rather than a fat and is present in serum as free cholesterol, 30 to 60 per cent, and as cholesterol esters of fatty acids. Levels are usually increased in conditions in which blood fat is increased and may be an indication of the amount of fat present. There is not a close parallel between these two findings and actually there may be a divergence. The blood cholesterol is little affected by the fat content of the diet but is increased by foods rich in cholesterol. With hyperthyroid disease the blood cholesterol is lowered; with myxedema, cretinism, and hypothyroidism the cholesterol is elevated. Blood cholesterol is most important as a confirmatory test in hypothyroid conditions and changes in level are important in following the effects of therapy.

Radioactive iodine (I^{131}) is a highly satisfactory isotope for clinical use. Given in amounts that are completely undetectable chemically, radioactive iodine may be traced by the energy released in nuclear disintegration. It has a half-life of eight days and the beta particles and gamma ray emissions permit ready detection with the apparatus currently available. To investigate thyroid disorders tracer doses are given as sodium iodide generally containing 5 to 50 μc. I^{131}. The dose, given in 6 ounces of water to a fasting patient, is followed by a normal meal. Determinations should be obtained routinely at 24 hours after the ingestion of the isotope. More frequent observation may be helpful to detect early excretion of I^{131}. Isotopographic drawings of detailed neck scanning, preferably to scale, on the tracings of the patient, are very useful.

A number of factors must be considered in evaluation of the radioiodine test. In the hyperactive gland, iodine will be picked up in greater amount and secreted in protein-bound form in higher concentration than in the normal gland. Thus, if only one observation is made, the usual time being 24 hours, the peak uptake may have been passed and the determination may fall within normal levels.

A second radioiodine test measures the conversion of inorganic iodine to the organic form in the thyroid and the secretion of protein-bound radioiodine into the blood (PBI^{131}). The PBI^{131} in the hyperthyroid patient will be elevated at 24 hours and continue to rise to higher levels at 48 and 72 hours. If the iodine uptake alone is used at 24 hours, 7 per cent of hyperthyroid patients will have values within the normal range. Using both determinations at 24 hours, this error can be significantly reduced.

In acute and subacute thyroiditis the radioiodine uptake and the PBI^{131} determinations are usually low in the acute phase and remain low as the inflammatory process persists. Sedimentation rate is usually elevated during the acute phase. In Hashimoto's thyroiditis the serum protein-bound iodine varies. The I^{131} uptake studies range from 6 to 83 per cent, and the PBI^{131} is always elevated to hyperthyroid levels. Thyroid stimulating hormone (TSH) administration will fail to produce a rise in the I^{131} uptake which, along with splenomegaly and abnormal liver function tests, may suggest Hashimoto's disease

complete removal from the plasma during a single circulation through the kidney. Thus, clearance of these substances reflects renal plasma flow and total renal blood flow may be calculated from the hematocrit value.

Maximal tubular excretory capacity is measured by increasing the plasma concentration of para-aminohippurate or Diodrast to a point where the maximal excretion rate of these substances is reached.

Maximal tubular reabsorptive capacity reflects the point at which substances normally absent in the urine appear as a result of increasing plasma concentration. Glucose is frequently used for this test since it is completely filtered but reabsorbed in the tubules up to a relatively constant maximal quantity. Beyond this maximal quantity, glucose appears in the urine and, thus, the capacity of the tubules to absorb substances may be accurately determined with this substance.

ENDOCRINE

Thyroid. A careful history and physical examination of the patient are of equal importance to the five commonly performed laboratory aids used in the diagnosis of thyroid disease (Table 8). The basal metabolism test (BMR), which is frequently performed and readily available, is a determination of the total energy produced by the combustion of food substances in the body under basal conditions; i.e., when the individual is fasting and is physically and mentally at rest and at ease. *The digestion of food will raise the* BMR by 10 to 15 per cent and any physical or mental activity will raise the determination proportionally. Several simple closed circuit machines are available for general use. Essentially, *the patient, in a fasting and basal state,* breathes into an air chamber containing an excess of O_2. The CO_2 is removed with a soda-lime filter. The volume of air in the apparatus is recorded on special graph paper, by which the oxygen consumed can be measured directly. Corrections are made for temperature, barometric pressure, and moisture, and the value obtained is then converted into energy equivalents (calories per hour) by standard tables. *The basal metabolism is usually* expressed in kilocalories produced per square meter of body surface per hour. Aub and DuBois' tables, based on surface area, are most extensively used. The standards of Benedict and Talbot *may* be used *for children.* Thus, the calories per square meter of body surface per hour are compared with the standard tables and a plus or minus per cent determination is obtained.

TABLE 8. Laboratory Findings in Normal, Hypothyroid, and Hyperthyroid Conditions.

Determination	Normal	Hypothyroid	Hyperthyroid
BMR	−10% to +15%	below −10%	above +15%
PBI	4–8 μg.%	below 4 μg.	above 8 μg.
I_{131}	20–50% uptake	below 20%	above 50% uptake
PBI_{131} (24 hrs.)	.010–.086%	.003–.054%	.085–1.45%
Cholesterol	110–300 mg.%	above 300 mg.%	below 110 mg.%

The basal metabolism, as expressed in kilocalories *per hour, is greater in early childhood* and decreases with age. It is 7 to 10 per cent lower in women as compared with men. The actual test is fraught with many chances for error. Some common errors are: leakage of *air around the nose clip, the mouthpiece, or* through a perforated ear drum; obstruction of valves; incomplete absorption of CO_2; and apprehension, restlessness, or discomfort on the part of the patient. Usually the test is performed *on three occasions to check the consistency* of the determinations.

Another disadvantage of the BMR is that changes of considerable magnitude may occur but still be without significance to the observer. *Although a patient with a BMR of* −10 per cent may have an elevation of 30 per cent to +20 per cent, this determination is not particularly significant without knowledge of a previous level. Therefore, objective *tests of thyroid function are more helpful.*

The protein-bound iodine (PBI) test is a definite aid to diagnosis in thyroid disease. The determination gives a direct estimate of the amount of circulating thyroid hormone, which is made up mainly of thyroxin, and is particularly useful in diagnosis of mild hyperthyroidism or hypothyroidism. *Present technics* permit the test to be performed with *accuracy in well-controlled laboratories.* Nor-

level this ion is mobilized from the bone resulting in demineralization. The excessive mobilization of calcium phosphate results in an elevation of the serum calcium level. Inorganic phosphorus in the serum of adults ranges from 3 to 5 mg. per cent and in children from 4 to 7 mg. per cent. Phosphorus in organic combination in the blood, particularly in the erythrocytes, is far greater than the inorganic phosphorus, but no information of practical clinical value has been obtained from its estimation. In hypersecretion of the parathyroid glands the phosphorus is usually low, the serum calcium becomes elevated, decalcification of bones takes place, and the patient exhibits signs of muscular weakness and hypotonia. Bone cysts and spontaneous fractures occur; the typical picture of osteitis fibrosa cystica. Large doses of parathormone or vitamin D may cause an increase in the phosphorus level due to the increased solubility of calcium phosphate. A high calcium, low phosphorus ratio may occur in myelomatosis and malignant metastases to bone. In hypoparathyroidism from parathyroidectomy, the phosphorus level rises as the calcium falls. With healing fractures the phosphorus level may be elevated. Advanced nephritis with acidosis will also cause elevation.

The normal alkaline phosphatase level is from 1.5 to 4 Bodansky units and is considered to be a good estimation of the osteogenic activity of recalcifying or newly calcifying bone. Hence, in the critical postoperative period following operation for hyperparathyroidism manifested by osteitis fibrosa cystica, it is extremely useful in predicting the amount of recalcification and the need for calcium. In the first few days after operation the determination may range from 2 to 20 Bodansky units, and will gradually return to normal over a period of several weeks.

Calcium excretion in the urine ranges from 0.1 to 0.3 gm. per 24 hours. Hyperfunction of the parathyroid glands, or injection of parathormone, causes an increase in excretion that results in a negative calcium balance.

The hyperexcretion of calcium in the kidneys results in supersaturation in the urine and deposition of calcium phosphate or oxalate crystals in the urinary tract. This may result in stone formation or in deposition in the renal parenchyma, and may lead to impaired renal function through either obstruction or damage to the renal cortex.

The normal phosphorus excretion in the urine is from 0.9 to 0.11 gm. per 24 hours, which is increased by hyperparathyroidism or the injection of parathormone. In patients with hypoparathyroidism, who are excreting large amounts of phosphorus, injections of parathormone fail to increase the output. This finding has been suggested as a test for hypoparathyroidism by Howard, et al.

Adrenal. The adrenal gland secretes three main groups of steroids.

The first group, called the "sugar hormones," is concerned with the maintenance of a normal blood sugar level. These steroids also modify carbohydrate, fat, and protein metabolism, permitting an individual to sustain long periods of fasting. They consist of corticosterone and hydrocortisone and are measured as 17-hydroxycorticoids in either blood or urine. In normal individuals the excretion in urine consists of 5 to 6 mg. per 24 hours. The second group is known as the "androgenic" steroids and is represented by such substances as adrenosterone and dehydroepiandrosterone. These steroids produce nitrogen retention and aid anabolic or anticatabolic processes. The adrenal androgens are measured in the female by determining the excretion of 17-ketosteroids. However, of the urinary 17-ketosteroids in the male, only two-thirds are derived from the adrenal while one-third is of testicular origin. Normal excretion in urine in males is 8 to 21 mg. per 24 hours and in females about half this amount, 4 to 14 mg. per 24 hours. The third type of steroids is the "salt-retaining" group of which the principal compound is aldosterone. It is possible to measure the output of aldosterone in the urine by assay methods but it is not commonly done. Adrenal insufficiency or hyperactivity may be manifested in acute or chronic form and may reflect changes in any or all of the three characteristic types of steroids produced.

HEMATOPOIETIC SYSTEM

The status of the blood and blood-forming organs is of vital significance to the surgeon in the diagnosis and treatment of surgical

and prevent unnecessary surgical intervention.

Thyroid carcinoma, particularly the papillary and follicular types, will take up, or can be caused to take up, radioiodine. The administration of propylthiouracil or TSH may cause the tumor or metastases to take up I^{131}. The undifferentiated carcinomas will not pick up iodine.

Radioactive iodine has been used to differentiate between benign and malignant nodules in nodular thyroid diseases. Malignant thyroid tissue concentrates less radioiodine than normal tissue. The so-called "hot" nodule is one that takes up more I^{131} than do other parts of the gland; the "cold" nodule collects less than the involved side. The "warm" nodule collects about the same I^{131} as the uninvolved gland. Thus the "hot" nodules, even if solitary, are usually benign, while about 10 per cent of the "warm" nodules and about 30 per cent of the "cold" nodules are malignant.

Parathyroid. The normal serum calcium level is from 9 to 11 mg. per cent (Table 9) which is only slightly affected by the oral intake of calcium. The level is largely regulated by parathyroid hormone which is secreted by the parathyroid glands. Calcium excesses are excreted by the kidneys and deficits are made up by mobilization of calcium from the bones. Prolonged decrease in calcium intake together with increased losses will result in a diminished serum level (Table 10).

TABLE 9. Normal Levels of Laboratory Tests Useful in the Study of Parathyroid Disease.

Test	Normal Level
Serum Calcium	9.0–11.0 mg.% (4.5–5.5 mEq./l.)
Serum Phosphorus	3.0–4.5 mg.% (1.0–2.3 mEq./l.)
Serum Alkaline Phosphatase	1.5–4.0 Bodansky units
Urine Calcium	0.1–0.3 gm./24 hrs.
Urine Phosphorus	0.09–0.11 gm./24 hrs.

TABLE 10. Types of Tetany (from Best & Taylor Physiological Basis of Medical Practice).

	Calcium	Bicarbonate	Chloride	pH	Phosphorus
Infantile or idiopathic tetany	Reduced	Normal	Normal	Normal	Normal or reduced
Tetany of osteomalacia	Reduced	Normal		Normal	Normal or reduced
Tetanies of sprue and celiac rickets	Reduced	Normal			
Gastric tetany	Normal	Increased	Reduced	Increased	Increased
Bicarbonate tetany	Normal	Increased	Reduced	Increased	
Hyperpneic tetany	Normal	Increased		Increased	
Parathyroid tetany:					
(a) Experimental	Reduced	Normal		Normal	Increased
(b) Post-operative	Reduced	Normal			
Phosphate tetany (Na_2HPO_4)	Reduced	Normal	Normal or increased	Normal or increased	Increased
Citrate tetany	Reduced				
Tetany due to calcium and vitamin D deficiency	Reduced				
Tetany due to magnesium deficiency	Normal				
Guanidin tetany	Normal or slightly reduced				Increased

Serum calcium exists in nondiffusible and diffusible forms. The former is bound to the protein molecule chiefly in the albumin fraction and comprises 45 per cent of the total (4 to 5 mg. per cent). Most of the diffusible calcium is in the ionized form. Variations in the total serum protein will influence the serum calcium level and therefore the calcium level varies directly with the protein level.

Parathormone acts on the renal tubules to increase the excretion of phosphorus. In attempts to preserve the serum phosphorus

level this ion is mobilized from the bone resulting in demineralization. The excessive mobilization of calcium phosphate results in an elevation of the serum calcium level. Inorganic phosphorus in the serum of adults ranges from 3 to 5 mg. per cent and in children from 4 to 7 mg. per cent. Phosphorus in organic combination in the blood, particularly in the erythrocytes, is far greater than the inorganic phosphorus, but no information of practical clinical value has been obtained from its estimation. In hypersecretion of the parathyroid glands the phosphorus is usually low, the serum calcium becomes elevated, decalcification of bones takes place, and the patient exhibits signs of muscular weakness and hypotonia. Bone cysts and spontaneous fractures occur; the typical picture of osteitis fibrosa cystica. Large doses of parathormone or vitamin D may cause an increase in the phosphorus level due to the increased solubility of calcium phosphate. A high calcium, low phosphorus ratio may occur in myelomatosis and malignant metastases to bone. In hypoparathyroidism from parathyroidectomy, the phosphorus level rises as the calcium falls. With healing fractures the phosphorus level may be elevated. Advanced nephritis with acidosis will also cause elevation.

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RBC 4.2 - 5.5 million

Hb. gms/100 ml ♀14-17 ♂12.8-15.2

PCV % ♀40-54 ♂37-47

MCV Cu.mic. 82-92

MCH ___ γγ27-31

MCHC ___ % 32-36

RETICS 0.5-2.5%

PLATELETS: 400,000-800,000

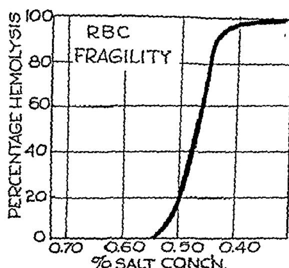
SICKLING Preparations:
Bisulfite ________
Sherman ________

BLEEDING TIME:
Ivy ___ 0.6 min.
Duke _ 2-4½ min.

RUMPEL-LEEDE neg.

ICTERUS INDEX 4-7 units

COAGULATION TIME:
Lee White _ 0.-15 min.
Silicone _ 60-90 min



SERUM IRON 100-150 γ% IRON BINDING PROTEIN 200-250 γ %

COOMBS TEST neg.

TOTAL IRON BINDING CAPACITY 300-350 γ %

UROBILINOGEN:

WBC 5,000-10,000

Urine max 0-4.0 mg /day Fecal - 40-280 mg./day

Hemolytic index {11-20 mgm fecal urobilinogen per 100 gms hemoglobin

DIFFERENTIAL:

BAS	EOS	MYEL	META	BAND	SEG	LYM	MONO
0-.075%	1-3%	0			54-62%	25-33%	3-7%

Fig. 7. Types of blood examinations with normal values performed in the Hematology Section, Department of Medicine, Tulane University School of Medicine.

conditions. It has become routine practice to examine the cellular elements of the peripheral blood as a part of examination of the patient. In many laboratories the routine blood studies performed upon hospital admission consist of erythrocyte, leukocyte, and platelet counts, measurement of hemoglobin concentration, packed cell volume, and microscopic examination of a stained blood film. This type of study will reveal most of the common abnormalities; i.e., anemia, polycythemia, leukopenia, leukocytosis, thrombocytopenia and the presence of abnormal cellular forms.

For a study of coagulation, the following tests are useful: 1. bleeding time; 2. clotting time; 3. prothrombin time; 4. prothrombin consumption; 5. thromboplastin generation; 6. cross-matching with plasma or serum from patients with known deficiencies; and 7. circulating anticoagulant test. In anemias it may be necessary to identify the hemoglobin type. This is particularly important when sickle cell anemia or thalassemia is suspected. The normal hemoglobins A (adult) and F (fetal) may be differentiated from the abnormal hemoglobins D, E, G, H, I, and J by three processes, namely alkali denaturation, electrophoresis (Tiselius), and paper electrophoresis.

The survival time of the erythrocyte can be measured by the injection of radioactive iron or sodium chromate, or of erythrocytes labeled with C-51.

Hematopoiesis is readily studied by examination of the bone marrow.

Whenever routine blood studies disclose an abnormality the nature of which is not readily apparent, consultation with a hematologist should be obtained. A list of blood examinations routinely performed in the hematology department at Tulane University and the normal values are shown in Figure 7.

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4

BACTERIAL INFLAMMATION

Historical Survey
Prophylaxis: Asepsis
Antisepsis
Surgical Bacteriology

Bacterial inflammation is also called infection and is due to the invasion of either normal or already damaged tissue by bacteria. Infection is evident clinically by the cardinal signs of inflammation, but in a much more violent degree, and by the frequent development of pus and of systemic manifestations such as fever, chills, and prostration. The details of spontaneous infections, wound infections and the role of chemotherapy will each be discussed in separate chapters. Here only the general features of bacterial inflammation will be described.

In the days before Lister discovered the nature of bacterial inflammation, surgical wounds practically always became infected. Surgical mortality therefore was high. The conquest of bacterial inflammation ranks in importance with the discovery of anesthesia, for together they were responsible for the tremendous advance in surgery during the past century.

HISTORICAL SURVEY

It is difficult for present day surgeons to realize the revolting conditions before the Listerian era. The offensive smell emanating from a hospital betrayed the presence of surgical patients. Nearly all operations were followed by suppuration, septicemia, or gangrene. The mortality was often appalling; if a patient had a simple laceration dressed in such a hospital, he would be almost sure to develop a serious infection. It is not surprising that Joseph Lister, as a young surgeon at Glasgow, on seeing these foul-smelling surgical wounds should have thought of the contemporary experiments of Louis Pasteur on fermentation and putrefaction. Indeed the surgical wounds of that day did putrefy It was undoubtedly the work of Pasteur which influenced Lister, even though it was Schwann in 1837 who first showed that putrefaction could be prevented by heat and was therefore due to living organisms. Lister, by analogy, argued that the putrefying wounds were also due to living organisms, but obviously he could not use heat on patients' tissues. To kill bacteria, therefore, he selected the antiseptic phenol, probably because it was then used to deodorize the putrefying sewers of the nearby city of Carlisle.

Lister, because he emphasized the use of chemicals to combat infection, is credited with being the discoverer of antiseptic surgery. Indeed, his paper in 1867 was entitled, "On the Antiseptic Principle in the Practice of Surgery." Although Lister's teachings now seem so obvious and fundamental, he spent a large part of his life defending his thesis and often found himself in bitter polemics with his English colleagues. In America, Lister's technic was also slow to become generally adopted. In Germany, however, his work was hailed with much enthusiasm and acclaim. His visit there in 1875 grew into a triumphal procession. It is to the Germans, moreover, that we owe our present ideas of aseptic surgery which is an extension of Listerism. Von Bergman, by introducing steam sterilization in 1886 and the elaborate aseptic ritual in 1891, is generally credited with originating the conception of aseptic surgery which really, however, is more of an outgrowth of the observations of Oliver Wendell Holmes and the Viennese obstetrician, Semmelweiss, than of the teachings of Pasteur and Lister. Pasteur

and Lister were concerned with living organisms and their eradication. Dr. Holmes knew nothing of bacteria, but did know that contact between one infected patient and another would result in a transfer of the infection, because something was carried from the first to the second patient and usually by the attending physician's hands; as early as 1842 he wrote advising doctors to cleanse their hands thoroughly before and after attending each parturient woman in order to reduce the incidence of puerperal fever. Semmelweiss, in Austria, made the same observation independently, although his first paper was not published until 1849. At that time childbed fever often played as much havoc in the lying-in hospitals as surgical infections did in the surgical wards. Like Lister in England, Semmelweiss entered into long controversies with his colleagues who generally refused to listen to his accurate and important teachings. Because of this he is said to have become utterly broken in spirit by the time he died. Recent historical studies by Kirkwood (1) have shown that Thomas Watson's observations antedated those of Semmelweiss and Holmes. In his *Lectures on the Principles and Practice of Physics* (1843) he described epidemics of puerperal fever in various parts of England as early as 1789 and stated unequivocally that "I believe them to be instances of direct inoculation."

The importance of contact contamination still forms one of the backbones of modern aseptic surgery. The principle was well expressed by Theodore Kocher, who was discussing many years ago the then widely debated question of the necessity of wearing rubber gloves during an operation. His surprising aphorism was to the effect that it was much more important to wear gloves *between* than during operations. This indeed would tend to prevent outside contamination. The use of rubber gloves in surgical operations was introduced by the American surgeon Halsted in 1890. Today the careful surgeon wears rubber gloves not only during an operation, but also whenever he touches infectious material, as, for example, when dressing or examining suppurating wounds. There must be no opportunity for any virulent organism to harbor itself on his hands. This should be true even outside of the hospital.

PROPHYLAXIS: ASEPSIS

The prevention of infection applies to wounds inflicted in the operating room as well as to those sustained accidentally outside. In general, the means used in the former are called asepsis, the latter antisepsis. Although there is considerable overlapping, each will be discussed separately. Chemotherapy as a means of prophylaxis is described in detail in the next chapter.

Asepsis. The principle of aseptic surgery is based largely upon the exclusion of all bacteria from the wound inflicted by the surgeon (Fig. 1). In this way healing takes place without infection; i.e., aseptically, or by first intention. The setup for maintaining such a technic is an elaborate one and requires attention to detail and painstaking daily and hourly scrutiny to see that no loopholes admit any offending organism. Such aseptic surgery is like a chain which is only as strong as the weakest link, and it is the problem of the surgeon and operating room personnel to see that no virulent bacteria get into the operative field, and through a break in technic create a weak link which destroys the entire scheme.

Such perfection in actual practice is almost impossible to attain, largely because of two sources of contamination.

The first source is the surgeon's hands and the patient's skin which, with the ordinary routine, cannot be rid of all of their bacterial inhabitants. Although the surface of the skin can be sterilized, the deeper epidermal layers as well as the recesses of hair follicles and sweat and sebaceous glands harbor organisms which are practically impossible to eradicate. The normal bacteriology of the skin has been well described by Lovell (2).

The second source of contamination is the bacteria in the dust of the air. Lister was much concerned with air contamination and used a carbolic spray, which may perhaps have killed the organisms in the air but proved to be too irritating and poisonous for general adoption. Air contamination may be greatly minimized by certain mechanical means mentioned below. However, it has been found that these two sources of contamination, i.e., skin and air, can be so greatly reduced that perfect healing will result. The

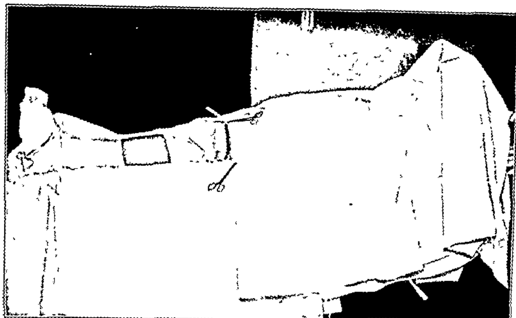


Fig. 1. Proper method of draping for an aseptic operation on the left lower leg.

following are the means by which this is achieved.

Methods of Surgical Sterilization. 1. *Mechanical means* comprise ordinary cleanliness by the use of soap, water, and scrubbing brush on the walls, floors, and ceiling of the operating room.

The area of the patient's skin about the proposed incision is also mechanically cleansed by careful shaving and washing. When shaving is carried out 12 hours or more before the proposed operation, scratches or tiny abrasions may be produced through which latent infection may occur. For this reason, many surgeons prefer to have the shaving carried out on the morning of operation.

The hands of all members of the surgical team are subjected to especially vigorous cleansing, particularly of the crevices under the nails and cuticles. Warm water is important for it promotes sweating, thereby bringing to the surface bacteria embedded in the depths of the sweat and sebaceous glands. The use of a good soap or the newer detergents improves the efficacy of mechanical cleansing, as discussed below. The stirring of dust from the floor is minimized by limiting the number of those walking about and by proper cleansing and treatment of floors to decrease dust. Clean, white shoes which have never been used outside are also advisable.

2. *Heat* is widely used in many ways to destroy bacteria, particularly in the sterilization of dressings, instruments, and other apparatus used during the operation. It is important to realize that destruction of bacteria particularly of spores, by heat, is due to coagulation of the bacterial protoplasm. This procedure requires the presence of moisture unless very high temperatures approaching that of an actual flame are used. For this reason, wet heat is much more efficient than dry heat; boiling water is much more effective than heated air. Most efficient of all is moist, *saturated steam vapor which is made to attain* a temperature much above that of boiling water by containing the steam in a closed chamber (autoclave) under sufficient pressure. The chief value of the increased pressure is its effect on raising the temperature. Thus, pure steam under a pressure of ten to fifteen pounds will attain a temperature of 115° to 120° C. (240° to 248° F.). Under such conditions the most resistant pathogenic spores will be destroyed in a very short time. Another great advantage of moist steam under pressure is its great penetrating power which enables one to sterilize large amounts of dressings, sheets, and such materials, if not too tightly packed. The condensation of the steam as it penetrates the cooler layers of fabric also aids greatly, for a thin film of moisture is thereby deposited and the local

temperature increased tremendously due to the liberation of heat during condensation.

3. *Chemicals* are of minor importance for sterilization, and even then only for surface sterilization. In the past, various chemicals were used for this purpose, as listed in Table 1, p. 67, now almost exclusively displaced by the synthetic detergents and other agents. The earliest of the former group were called cationic detergents, a popular example of which was Zephiran. Most of them were not only cleaning agents with bacteriostatic properties, but also left microscopic protective films over the skin. Unfortunately, bacteria continued to gather under the film from the deeper recesses and were released when the film was broken. A more recent and commonly used preparation is a combination of a good soap and hexachlorophene, which is a bacteriostatic agent and also forms a protective film over the skin. Some surgeons use a 3 per cent hexachlorophene in 90 per cent propyl alcohol, and 10 per cent dodecyl alcohol. The film produced is then removed by scrubbing the area later with a soap containing the same chemical. In an extensive study by Freeman and Young (3) a great diminution in the incidence of wound infection was found following the use of a synthetic detergent for skin preparation. Thus in 1,200 control cases in which the usual technic was employed, 7 per cent of the cases showed evidence of wound infection whereas, with the use of the synthetic detergent, only one serious infection and three stitch abscesses were noted in 1,100 consecutive cases. Phenol, the backbone of Lister's antiseptic technic, is rarely used now except to cauterize infected tissue and to sterilize sharp instruments which might be dulled by boiling. Gaseous formaldehyde is often used to sterilize cystoscopic and bronchoscopic instruments.

4. Gentle irrigation of the wound after closure of the fascia, using isotonic saline, tends to remove particles of fat, debris, and even bacteria released from the deep layers of the skin. A microscopic study of the location and distribution of these skin bacteria has been reported by Lovell (2). That bacteria actually are frequently present is shown by a study by Hunt (4), of 28 clean abdominal wounds just before skin closure. Culture of the wound secretion showed 40 to 1,680 bacterial colonies in all but three cases, even though 19 healed with no evidence of infection, and the remainder showed only a mild exudate between the skin edges, or around the sutures. The one case with 1,680 colonies developed a mild postoperative thrombophlebitis.

Wounds treated by gentle irrigation before closure are much more likely to heal drier and with less moisture around the sutures or between the skin edges.

Breaks in Aseptic Surgical Technic. The development of a postoperative wound infection in what should have been a perfectly healed incision means, of course, that bacteria have slipped in through some loophole in spite of the elaborate precautions; the chain has developed a weak link. It is important, therefore, to make careful observations of all such infections, even though trivial, and to culture the pus in order to identify the contaminating organism. Each step in the preparation of dressings, solutions, and instruments must be carefully investigated, sterilizers checked, autoclaves examined, and chemical solutions analyzed bacteriologically. Air-borne contamination from dust is also investigated and eliminated as far as possible, along lines already discussed. In most cases, however, the fault lies with the surgeon, operating team or personnel (Fig. 2).

These may be described as follows:

1. The *mouths and throats* of the operating room personnel emit countless bacteria into the air with each expiration. These cause no trouble ordinarily when efficient masks are worn. To be effective, masks must efficiently strain the exhaled air of all droplets. Masks containing an impermeable layer such as cellophane are unsatisfactory because they merely deflect the exhaled air. Much more practical and scientific is the use of such substances as cellucotton or flannel (de Takats 5) which have more of a tendency to filter the exhaled air. Masks must cover both mouth and nostrils, and of course must be comfortable to the wearer. They must be worn by all entering the operating room. When droplets are ejected while talking, or especially by coughing, sneezing, laughing, or clearing the throat, the danger of air contamination is greatly increased, even though masks are worn. Such actions are therefore

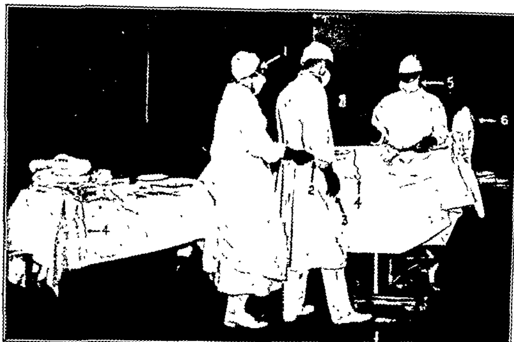


Fig. 2. Common errors and breaks in technic to be guarded against in the operating room: 1, nurse's hair incompletely covered by cap; 2, passing instruments should never be done behind another person; 3, the gloved hand should not fall to the side but must be kept above the level of the operating table; 4, sutures must not be allowed to drag below the field of operation; 5, the nose as well as the mouth must be covered by the mask; 6, draping over the anesthetic screen must be complete.

interdicted in the operating room, especially over an open wound. Regardless of masks, moreover, the presence of any person with a respiratory infection in an operating room courts serious danger, not only because such individuals are likely to cough uncontrollably, but, of more importance, the bacteria they exhale are so virulent that the deposition of relatively few on the wound may result in a serious infection. The importance of proper circulation of uncontaminated air through the operating rooms in the prevention of wound infection has recently been emphasized by Ross and associates (6).

2. The *skin of the surgeon's hands* as well as that of the other members of the team form a second source of contamination. The danger of contact infection has already been emphasized. The presence of infected lesions on the hands, even if slight, should exclude the individual from scrubbing up for the operation, because rubber gloves are not absolute in their protection. Not only are they porous, but they may become torn or punctured, sometimes without being noticed, and virulent organisms spilled into the wound (Fig. 3).

Contamination of the surgeon's hands outside the operating room may persist despite the usual preparation. As mentioned earlier, this was the reason Kocher suggested, perhaps facetiously, that the surgeon wear rubber gloves before rather than during operation. Nevertheless, it might be worthwhile to follow the suggestion of Poth that all surgeons use a soap containing hexachlorophene whenever they wash their hands as part of their routine toilet.

3. The *patient's skin* is a third link which may weaken the chain. Unless the operation is urgent, the presence of even minor infections in the field of the proposed incision contraindicates operation until the furuncle, dermatitis, or ulcer is healed. The presence of a large abscess anywhere, even though not in the field of operation, may also be a possible source of contamination. If the patient has a respiratory infection the same danger is present. Such infections may give rise to a bacteremia which will lead to a wound infection by the deposition of blood-borne organisms in the field traumatized by the surgeon. In such cases when the operation is one of election it is safer to wait until the offending lesion is healed.

4. A fourth loophole is *faulty sterilization*



A



B



C



D



E



F

Fig. 3. Various steps in the process of "scrubbing up," or aseptic preparation. A, scrub the hands and arms up to and above the elbows for ten minutes with a brush, soap, and running water; B, allow water to drain off the elbows; C, dry hands and arms with a sterile towel; D, bathe the hands and arms in alcohol or acetone solution; E and F, proper method of putting on gloves unassisted. Note that the outside of the glove is not touched by the skin. The use of synthetic detergents has shortened the period of "scrubbing up" and made it more efficient.

with autoclaves. As mentioned above, only moist heat under pressure effectively destroys spores. The presence of air in the autoclave, improper packing of supplies, etc., may seriously interfere with effective sterilization.

5. *Catgut* is a fifth possible source of contamination since it is prepared from an infected tissue, i.e., the lower small intestine of sheep. Constant and alert precautions on the part of the makers of catgut usually yield sterile sutures, but the danger is nevertheless present and numerous instances of infected catgut have been reported.

6. A final loophole in the aseptic scheme may occur by a *gross break in technic*, i.e., touching a sterile with a nonsterile object. Every surgeon and nurse must have an almost automatic alertness about such sources of contamination, a sort of second nature which makes it literally impossible for any nonsterile object to touch the field of operation or anything which comes in contact with it.

Other Factors in Prophylaxis. Although the methods just outlined, if rigidly carried out, will eliminate most bacteria from the operative field, a few may persist in the deep layers of the patient's skin or enter from those circulating in his blood. Most surgeons realize, however, that these few bacteria do not interfere with perfect healing because, with good surgical technic, the wound can easily cope with them without infection. Emphasis must be placed, therefore, on the fact that these bacteria become important only when their multiplication is aided and abetted by faults of operative technic, factors which are never overlooked by careful surgeons. Most of these factors of operative technic are described in detail in later chapters. They comprise such features as the *gentle handling of tissue*,—so aptly emphasized recently by Ross (7)—*careful hemostasis, and avoidance of tension* in placing sutures; emphasis on these and other similar details formed an important part of the teaching of W. S. Halsted and others before the beginning of this century. Halsted also made numerous technical contributions such as rubber gloves, silver foil, gutta percha drains, and others.

Halsted was also an early advocate of the use of silk rather than catgut for sutures because, among other reasons, he felt that fine silk insured more careful technic, itself an important factor in aseptic healing. The trend toward the greater use of silk has continued, especially in more recent years. The reports by Whipple, Meleney, Howes, and Harvey over two decades ago, on the role of the suture in wound healing and in infection, probably played an important part in this change. Suture material is discussed in more detail in Chap. 14.

ANTISEPSIS

In contrast to asepsis, antisepsis finds its modern application in the accident room where wounds are seen which were sustained outside the hospital and often under conditions of maximum contamination, so that the open tissue is covered with millions of bacteria. A clear distinction should here be made between a contaminated wound and an infected wound. The difference is one of time and of treatment. Most badly contaminated wounds will become infected in the course of time without treatment. Some mildly contaminated ones may heal per primam. Only time tells. However, if a badly contaminated wound is seen early enough and the contamination adequately eliminated before the bacteria have gained a foothold, infection can almost always be prevented (see Chap. 14). To accomplish perfect healing is, therefore, the aim even in such cases. Here, indeed, is practiced true antiseptic surgery after the manner of Lister. If antisepsis is achieved and the wound is rid of the contaminating organisms the necessary surgery can then be done and the wound closed with all the precautions of aseptic surgery and perfect healing will follow. Mechanical means such as cleansing and débridement, as described in detail later, are much more important than antiseptic chemicals.

In open contaminated wounds, moreover, antiseptics may do much damage by injuring tissue cells as well as bacteria so that in order to prove noninjurious to the patient they have to be diluted to a degree which makes them innocuous to the germs as well.

A comparative study of various antiseptics completed many years ago is summarized below because it is so classic, and the authors (Salle and Lazarus 8) measured the effect of the chemical on tissue cells as well as on bacteria (Table 1).

TABLE 1. Comparison of Action and Efficiency of Various Antiseptics
(After Salle and Lazarus, 8)

Antiseptic	Highest Dilution Showing No Tissue Growth = A	Highest Dilution Showing No Growth of S. aureus = B	Toxity Index = A/B	Phenol Coefficient
Iodine (Lugol's solution)	1-1,800	1-20,000	0.09	308
Hexylresorcinol	1-21,000	1-7,000	3.0	108
Metaphen	1-76,000	1-6,000	12.7	92
Phenol	1-840	1-70	12.0	...
Merthiolate	1-176,400	1-5,000	35.3	70
Mercurochrome	1-10,500	1-40	262.0	0.6

The number expressing the relationship between the dilution inhibitory to cell and to bacterial growth was called the toxicity index. These workers found that iodine in aqueous solution (dilute Lugol's solution) was the only antiseptic more toxic to bacteria than to cells. To this should perhaps be added proflavine and 2:7-diamino acridine, two acridine drugs investigated in England, and found to be the only ones among many tested, which, at a 1:1000 concentration, produced a minimal injury to brain tissue in vivo and the least effect on the metabolism of brain tissue in vitro.

The use of such chemicals in the antisepsis of wounds represents a "test-tube" conception in therapy which is tending more and more to be of historical interest only. The advent of modern chemotherapy with sulfonamides and the many antibiotics has initiated a change toward a more biologic approach. Antibiotics—used singly (9, 10) or in combination (11, 12)—are very effective in the prevention as well as treatment of infections. However, as has been emphasized by Altemeier and associates (13), antibiotics cannot take the place of good surgical technic.

SURGICAL BACTERIOLOGY

Surgical bacteriology may be defined as the application of bacteriological knowledge to the diagnosis and treatment of surgical infections. Most surgical infections are associated with wounds; many, however, develop spontaneously or after slight or indetectable injuries. The latter become surgical because they produce lesions such as abscesses, which require incision and drainage or other surgical procedures.

Classification of Bacteria. Only a few of the many bacteria will be discussed in detail; the following classification is based on the shape, the staining properties, and the anerobic or aerobic properties of growth. Other features of bacteria may be learned by consulting standard bacteriology texts.

CLASSIFICATION OF BACTERIA

Those of most importance to the surgeon are in boldface type
(Modified from Meleney, 14)

CLINICAL OCCURRENCE

I. Aerobic Bacteria
  A. Cocci
    1. Gram-positive
       Streptococci: erysipelas, acute cellulitis, septicemia, acute pyogenic arthritis, osteomyelitis, empyema
       Staphylococci: furuncles, carbuncles, osteomyelitis, septicemia, infected wounds
       Pneumococcus: empyema, peritonitis, acute arthritis
    2. Gram-negative
       Gonococcus (*Neisseria gonorrhoeae*): pelvic disease, urethritis, prostatitis, acute joint infection
       Meningococcus (*Neisseria meningitidis*): meningitis
  B. Bacilli
    1. Gram-positive
       Mycobacterium tuberculosis: infection (bones, joints, meninges, lungs, lymph nodes, peritoneum)
       Bacillus anthracis: anthrax
       Corynebacterium diphtheriae: throat infections, wound infections (very rare)
       Clostridium botulinum: botulism

2. Gram-negative
   - *Escherichia coli:* peritonitis, appendiceal abscess, cystitis
   - *Salmonella typhosa* (*Bacillus typhosus*): typhoid fever, osteomyelitis, perforation of ileum, cholecystitis
   - *Bacillus mucosus capsulatus* (*Klebsiella pneumoniae*): pneumonia, empyema
   - *Proteus vulgaris* (*Bacillus proteus*): secondary invader
   - *Pasteurella tularensis* (*Bacillus tularense*): tularemia
   - *Pseudomonas aeruginosa* (*Bacillus pyocyaneus*): secondary invader
   - *Actinobacillus mallei:* glanders
   - *Haemophilus influenzae:* acute arthritis, empyema
   - *Haemophilus ducreyi:* chancroid
   - *Streptobacillus moniliformis:* rat-bite fever

II. Anaerobic Bacteria

A. Cocci

Streptococci: peritonitis, mouth infections, pelvic infections

B. Bacilli

Clostridium novyi
Clostridium sporogenes
Clostridium histolyticum
Clostridium tetani
Clostridium perfringens (*Bacillus welchii*)
} gas gangrene

C. Spirochetes

Treponema pallidum: syphilis (bones, joints, meninges, skin, etc.)
Treponema pertenue: yaws

III. Higher Bacteria: mycotic organisms (fungi and yeasts)

A. Actinomycetes: actinomycosis, madura foot, nocardiosis
B. *Candida albicans* (*monilia*): moniliasis, diarrhea, thrush
C. *Histoplasma capsulatum:* histoplasmosis
D. *Coccidioides immitis:* coccidiodal granuloma, coccidiosis
E. *Blastomyces dermatitidis:* blastomycosis
F. *Cryptococcus histolyticus* (*Torula histolytica*): torulosis

The bacteria of greatest importance in acute surgical infections are the *pyogenic bacteria.* The term "pyogenic" (pus-forming) is usually applied to all of the following organisms though only the staphylococcus is a typical pus-producer. Moreover, the tubercle bacillus, though not a pyogenic bacterium, may in cold abscesses produce typical thick, creamy pus. Nevertheless, the term is generally used to apply to the staphylococcus, streptococcus, pneumococcus, colon bacillus, and pyocyaneus bacillus. Chemotherapy, especially with the broad-spectrum antibiotics, has a great influence on the pathogenicity of many bacteria as discussed in detail in a separate chapter. Here only the basic features of those mentioned will be described.

The *staphylococcus* exists in at least three forms, the aureus, albus, and citrus; the modifying terms are based on color the colonies produce on culture. Inasmuch as the staphylococcus occurs as a normal inhabitant of the skin, it is sometimes difficult to determine whether the organism isolated from many infections represents a pathogenic strain or an accidental contamination. In general, a staphylococcus which is hemolytic, which is of the aureus type, and which is coagulase-positive is most apt to be pathogenic. Pathogenic staphylococci cause rapid suppuration, forming thick, creamy pus with a sweetish odor which has a tendency to remain localized as an abscess and break through to the outside, eventually healing without difficulty. The favorable outcome which thus followed staphylococcus infections led the ancients to call its pus "laudable." Many, in fact, believed that healing could not occur without the formation of this pus. On the other hand, it is now known that the staphylococcus may incite serious infections such as septicemia and pyemia, and in such cases has been cultivated from the blood stream.

Staphylococci, perhaps more than any other bacteria, have been greatly influenced by the advent of chemotherapy (see Chap. 5). The wide use of penicillin has so attenuated the virulence of many strains that many other strains formerly nonpathogenic and insensitive to penicillin are now producing disease.

The *streptococcus* occurs in several well-known types or strains, i.e., hemolytic, non-

hemolytic, viridans, and anaerobic. Other classifications have divided this organism in other groups depending on sugar fermentation and other properties. It is a normal inhabitant of the oral cavity and vaginal tract and is present in the intestinal contents. When virulent, it is a much more serious invader than the staphylococcus, for it tends to spread and involve wide areas of tissue, causing necrosis without localizing tendencies. Moreover, there is much less tendency to form pus; when pus forms it is usually watery in character though later it becomes thick. Streptococcus is the etiological agent in erysipelas, scarlet fever, acute tonsillitis, and a host of other infections. The anaerobic streptococcus is also a serious invader and is encountered in various pelvic infections, peritonitis, symbiotic infections, and the like. It was the first to be conquered by the sulfonamides early in the modern era of chemotherapy.

The *E. coli* is a normal inhabitant of the lower bowel and, as might be expected, is the main invader after appendiceal infections. It also escapes through the bowel wall in cases of secondary peritonitis from any other such cause as various types of perforation. Pus produced by the organism has an offensive fecal odor and, though in the early stage it is thin, brownish, and watery, it later becomes thicker. Gas may be associated with it. Infections of the gallbladder, liver, and genitourinary tracts are also often due to the *E. coli.*

The *pneumococcus,* though chiefly confined to lung infections, is met with in surgery when such infections are followed by empyema. The pus in such a case, though at first thin, rapidly becomes thick, creamy, and mucoid and contains much clotted fibrin. The pneumococcus may also cause primary peritonitis in children and is the offending organism frequently in acute pyogenic arthritis and sometimes in meningitis. The meningococcus is the invader, however, in epidemic meningitis.

The *Pseudomonas aeruginosa* (*B. pyocyaneus*) is of little pathogenic importance, but is often seen as part of a mixed infection, particularly in large wounds containing necrotic material or over large granulating defects. It betrays its presence by the development of a greenish or bluish discoloration of the discharge and by its peculiar musty odor. It is often associated with *Proteus vulgaris* (*B. proteus*). Various methods have been devised to eliminate these otherwise saprophytic organisms, by means of various bactericidal agents. The most effective way of eliminating them is the removal of necrotic tissue from the wound.

Other bacteria are also important to the surgeon. Mention should be made of anaerobic and microaerophilic organisms, especially, the streptococci which are present in certain puzzling chronic ulcers (see Chap. 8). Spores are also important because they resist ordinary means of antisepsis and may reside in contaminated wounds for years without activity after healing has occurred. The development of the spores into their active vegetative form may occur subsequently after sufficient trauma. Spores occur commonly in tetanus and gas gangrene, which are discussed later. Ordinary pyogenic bacteria may also become dormant under certain special conditions, particularly when they are present in infected compound fractures. Healing may occur, but the organisms remain viable and may set up a severe infection years later if the involved bone is traumatized again for any reason.

Of special importance in the wake of chemotherapy is the conversion of saprophytes to pathogens (see page 85). Pseudomembranous ulcerative colitis may then develop because of the invasion of staphylococci, salmonella, *B. proteus,* and even of monilia.

The Virulence of Bacteria. The disease-producing powers of bacteria vary tremendously. Only a few of the factors will be discussed; they are really to be considered along with the factors influencing the resistance of the body which are described in the next section.

The *strain* or *kind* of bacterium is obviously important. Many of these differences have already been described.

The *number of bacteria* undoubtedly plays a role in virulence. An open wound can ordinarily take care of a certain number of microorganisms without any perceptible increase in the degree of the inflammatory reaction. Wounds which have healed per primam have repeatedly been shown to contain a certain number of bacteria. If the number is too

great, phagocytosis may be ineffective and, by force of numbers alone, the bacteria may set the stage for a real infection.

Foreign bodies and necrotic tissue in a wound contribute to the severity of any infection. This was not generally realized until World War I, during which surgeons of many nations were confronted with millions of wound infections. A clean bullet wound through the thigh, for example, was apt to heal perfectly. Shrapnel wounds, which nearly always contained much foreign material and jagged necrotic tissue, were the most seriously infected. On the other hand, if foreign bodies and devitalized tissue were removed (débridement) within a few hours after the wound was received, the incidence of infection was slight or absent. The medical manuals of all nations finally came to prescribe débridement of such wounds as the primary form of treatment. In acute peritonitis, this influence of necrotic material in increasing virulence has been shown experimentally. Dogs will withstand the injection of large numbers of certain bacteria into the peritoneum without infection; only when bits of sterile agar, muscle, or other foreign bodies are implanted at the same time does a fatal peritonitis follow. In chronic draining sinuses, the role of foreign bodies in maintaining infection is also well known and is described elsewhere in the text.

The time factor in removing foreign bodies and devitalized tissue as a means of reducing the virulence of infections was put into wider practice in World War II and in the Korean conflict. Wounds were seen and treated within an hour or two, i.e., as close to the front line as possible. Better air transportation also helped.

Bacterial symbiosis or *synergism* has also been shown to increase bacterial virulence in certain surgical infections. Many of these observations have been made by Meleney (14). Clinically, such symbiosis undoubtedly explains certain extensive spreading ulcers of the abdominal wall and other parts of the body. The serious nature of human bites which inoculate a mixed group of mouth organisms into the wound may perhaps be explained on this basis. Peritonitis, often caused by a mixed infection, may also owe its high mortality to bacteria acting synergistically, particularly when there is a perforation of the appendix or other viscus.

Chemotherapy, although of great value in the prophylaxis and treatment (15) of infection, has had an adverse effect, as already mentioned, by greatly increasing the virulence of many hitherto nonpathogenic staphylococci (16, 17). This effect on other bacteria is less known but may ultimately prove to be just as important (see page 85).

The Resistance of the Body. The possession of resistance by the patient is often spoken of as his immunity, which may be local or general or both. *Local immunity* depends somewhat on the type of tissue, especially its vascularity. The term is mostly used to describe the local resistance which an area develops after fighting off an infection so that the same organisms can no longer invade at this point at least, though it may still get a foothold in some other part of the body. After a consideration of the available evidence Topley (18) concludes that "it is possible to induce an immunity which is confined to the neighborhood of the treated area, and is not shared by the body as a whole." On the other hand, local immunity may sometimes be decreased, presumably by an increase in local tissue sensitization. This may explain the susceptibility of meat cutters, fish handlers, and milkers to repeated streptococcal cellulitis, often called eryspeloid.

The resistance of the body ordinarily is largely due to a *general immunity,* which declines in the presence of shock (Fine 19) and other abnormal states. The possession of such immunity is specific and resides in the body as a whole, although the protein, particularly the gamma globulin, fraction of the plasma and the cells of the so-called reticuloendothelial system (plus other leukocytic and phagocytic cells), are supposed to be primarily involved in the mechanisms of immunity. A third and important factor in resistance is the protective action of the lymph nodes. The development of leukocytosis during infections is also a manifestation of resistance. The various metabolic responses to infections, wounds, and other conditions have been discussed in detail by Moore and Ball (20). *Natural* (innate) *immunity* refers to resistance inherent or at least obtained in some unknown spontaneous way or congeni-

tally. *Acquired immunity*, on the other hand, is the result of defenses built up in fighting a previous infection. *Artificial immunity* is a similar defense obtained, however, by one of two methods of treatment, i.e., passive or active immunization. Of the two, the latter is especially important in the prevention of tetanus (see page 102).

Malnutrition, especially protein deficiency, often impairs the patient's resistance to an operative load (21) and to at least certain infections. This is certainly true of tuberculosis and probably true of certain pyogenic infections. Cannon (22) has investigated the role of nutritional deficiencies in relation to immunity and has shown clearly, in certain cases at least, how important this factor may be.

Bacterial Diagnosis. Identification of the causative bacterium is most important in all surgical infections, not only in diagnosis and prognosis, but especially in therapy. If specific therapy is indicated or if chemotherapy is to be used, such identification is not only essential but should be made as early as possible. In order to detect bacterial synergism, isolation of more than one organism is obviously necessary. Unfortunately, in the routine methods used in most surgical infections, negative findings are the rule—the report usually comes back "no growth." Such negative information often means failure on the part of the surgeon to observe adequate care in the collection and handling of the infected material. A common error in intraperitoneal infections is to collect only the turbid fluid which escapes as the peritoneum is first opened. It is far better to wait until the source of infection is located and true pus encountered before removing a portion for bacteriological study.

Bacterial diagnosis may be especially important in selecting an effective chemotherapeutic agent. The tests for in vitro sensitivity of bacteria to the many agents now available is discussed elsewhere (see page 78).

Examination of pus is the most direct method of bacterial diagnosis but must be carried out immediately after the abscess is opened. Delay often leads to failure because the lesion is rapidly invaded by secondary organisms. The first and easiest step in the study of pus is to make an appropriately stained smear on a glass slide. The smear may show the nature of the leukocytes, whether polynuclear or mononuclear, as well as bacteria. If the smear shows no bacteria, cultures must be made, preferably under both aerobic and anaerobic conditions. Injection of the pus into guinea pigs or other animals may be important in establishing or ruling out a diagnosis of tuberculosis. For adequate bacteriological examinations it is best to obtain several cubic centimeters of the pus itself. Pus is much more likely to contain organisms if obtained from the *wall* of the abscess. If the amount of pus is small, it is preferable to collect it on a cotton swab which should first be moistened with sterile saline inasmuch as a tiny amount of pus will otherwise be soaked up by the cotton and be lost. Cultures should be made promptly or the material kept in an ice box; if left at room temperature the organisms may die by drying. Some organisms are so sensitive to a change of temperature that they should be cultured immediately when they are removed from the body. In certain cases, part of the tissue lining the abscess should be removed (biopsied) for special bacteriological study. In the case of a lymph node removed for diagnosis, a good plan is to divide it in half, using one for microscopic study and reserving the other half in a sterile, tight, glass container (Petri dish) in the deep freeze for later bacteriological study if necessary.

Blood culture, when positive, is often the only way of identifying the causative organisms in cases where no pus is obtainable. Unfortunately, a blood culture is not always positive even when organisms are present; the power of the blood to rid itself of bacteria is tremendous, at least partially by virtue of the astonishing phagocytic activity of the reticuloendothelial cells which line the blood channels, especially of the lungs, liver, and spleen. Millions of bacteria or tiny foreign particles have been injected into the blood streams of experimental animals only to disappear within a few hours. In general, the greater the number of bacteria found on blood culture, the more serious the infection. Aside from the number of organisms a positive blood culture has considerable prognostic value, as shown on analysis of a large

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series of streptococcus infections by Keefer, Ingelfinger and Spink (23).

Other methods of bacterial diagnosis are often of considerable importance. Microscopic study of biopsied material may be useful in certain cases, especially in the chronic granulomatous infections, e.g., tuberculosis, actinomycosis, and syphilis. Agglutination tests applied to the blood are very useful in typhoid and tularemia. Doubtless with further study many more infections will become thus more easily detected.

Specific Immune Therapy. Specific therapy with such bacteriologic material as antitoxins have, in general, been of more value in medical than in surgical infections. The use of serums and vaccines must, in any case, be carefully evaluated before adopting them because of the tendency for therapeutic applications of bacteriologic research to far outstrip justifiable indications. *Vaccines* are suspensions of bacteria which have been killed by heat or chemicals and are then injected subcutaneously, intramuscularly, or intravenously. As a prophylactic measure against specific infections to which the patient might be exposed in the near future, vaccines have undoubtedly been responsible for saving many lives (e.g., typhoid prophylaxis). Vaccines were formerly used prophylactically in recurrent staphylococcus infections (furunculosis) in which each focus is assumed to be too mild to instigate sufficient antibody formation. Once an infection has gained a real foothold, the value of vaccine is open to question. The wholesale use of vaccines, once heralded as a cure for practically every infection, has rightfully fallen into desuetude. *Bacteriophage* is responsible for the rather rapid dissolution of certain bacteria in culture on addition of Berkfeld filtrates from other cultures. This remarkable breaking up of bacteria has thus far failed to find a proved place in the treatment of infections, although therapeutic claims have been made and much stimulating research is still going on. *Serums* are used as vehicles for administering specific antibodies, such as antitoxins; usually the serum is that of the horse in which antibodies have been produced by previous treatment with a specific antigen. Such specific therapy is spoken of as passive immunization. The great disadvantage and even danger in the use of serums to confer passive immunity is the possibility of foreign protein reactions. This type of allergic response is produced by certain drugs and chemotherapeutic agents (24). Examples of specific antibodies of value in surgery are largely confined to prophylaxis as in tetanus. However, prophylaxis in tetanus is achieved much more effectively by means of active immunization with the use of tetanus toxoid as described on page 102. This achieved widespread success, particularly during World War II.

The use of repeated blood transfusions for the purpose of carrying specific antibodies, has largely historical interest. Beneficial clinical results from transfusions can be expected only for purposes of correcting sufficiently severe hypoproteinemia and anemia. The extensive use of chemotherapy has also tended to replace the use of specific antibodies in the treatment of infection and will be discussed in a separate chapter.

Recently, *properdin*, an euglobulin in peripheral plasma, has been claimed to play an important part in the defense system against bacterial invaders. Normally present in plasma, it is not an immune body and is nonspecific. Commercial production has not yet been achieved to the extent needed to test its value for general clinical use (see Chapter 14 for details).

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Within a year after Domagk's report, Fourneau and his co-workers at the Pasteur Institute in Paris made the amazing discovery that the dye was broken down in the body, yielding paraminobenzine sulfonamide, a white crystalline substance which was really the active chemotherapeutic agent. This compound, whose more popular name is sulfanilamide, had actually been known since 1908 without any suspicion of its potent therapeutic property. Sulfanilamide, moreover, was not protected by manufacturers' patents as was the case of Prontosil, and it therefore came into extensive use rapidly throughout the world. Thus was initiated the new era in chemotherapy. Soon many other varieties of related substances were studied, all of them designated by the generic term of sulfonamide. The idea that the sulfonamides were not actually germicides in the old sense, but owed their effectiveness to their adverse action on the normal metabolism of the invading organism was soon amply confirmed by many observers.

Only those who remember the great virulence of many of the streptococcal infections of the past can appreciate the dramatic nature of this new discovery. Unfortunately, however, the sulfanilamides were ineffective against the staphylococcus. This need was soon met, however, by the discovery and development of penicillin in England. More important than this was the fact that the new agent initiated an entirely new kind of investigation which yielded a quite different type of potent chemotherapeutic drug. Unlike the sulfonamides, these new antibacterial substances were not produced by chemists, at least at first, but could only be obtained through the growth of living microorganisms themselves. For this reason, the new group of drugs was called antibiotics, i.e., products of the biological activity of one organism which were effective against others. Such a phenomenon had actually been known since the time of Pasteur as bacterial antagonism, yet it remained for an English physician and bacteriologist to discover penicillin, a substance resulting from the growth of a mold, which inhibited the growth of staphylococcus. Moreover, it was quite nontoxic even in large doses. Dr. Fleming himself tells the story of the discovery of penicillin (2) as follows:

The story of penicillin has often been told in the last few years. How, in 1928, a mould spore contaminating one of my culture plates at St. Mary's Hospital produced an effect which called for investigation; how I found that this mould—a *Penicillium*—made in its growth a diffusible and very selective anti-bacterial agent which I christened Penicillin; how this substance, unlike the older antiseptics, killed the bacteria but was non-toxic to animals or to human leucocytes; how I failed to concentrate this substance from lack of chemical assistance, so that it was only 10 years afterwards, when chemotherapy of septic infections was a predominant thought in the physician's mind, that Florey and his colleagues at Oxford embarked on a study of antibiotic substances, and succeeded in concentrating penicillin and showing its wonderful therapeutic properties; how this happened at a critical stage of the war, and how they took their information to America and induced the authorities there to produce penicillin on a large scale; how the Americans improved methods of production so that on D day there was enough penicillin for every wounded man who needed it, and how this result was obtained by the closest cooperation between governments, industrialists, scientists and workmen on both sides of the Atlantic without thought of patents or other restrictive measures. Everyone had a near relative in the fighting line and there was the urge to help him, so progress and production went on at an unprecedented pace.

Penicillin is the most powerful chemotherapeutic drug yet introduced. Even when it is diluted 80,000,000 times it will still inhibit the growth of staphylococcus. This is a formidable dilution, but the figure conveys little except a series of many naughts. Suppose we translate it into something concrete. If a drop of water is diluted 80,000,000 times, it would fill over 6,000 whiskey bottles.

Within a decade other microorganisms were found to produce antibiotics. In 1939, Dubos discovered tyrothricin which he obtained from ordinary soil bacteria. Other substances were later found from similar organisms, but their therapeutic application in human disease was handicapped in general by their toxicity when used systemically. However, polymyxin B has been successfully used (3) especially for eradicating the *Pseudomonas aeruginosa* (*B. pyocyaneus*) which is resistant to most other antibiotics.

Much more fruitful has been the group of actinomycetes, first studied by Waksman,

5

CHEMOTHERAPY IN SURGERY

Historical Survey
General Principles of Chemotherapy
Selection of Chemotherapeutic Agents
Prophylactic Therapy
Definitive Therapy
Untoward Reactions

Chemotherapy in its widest sense refers to the use of specific chemicals to combat any designated disease, including cancer. This does not mean that cancer is necessarily an infection, but that certain chemical agents, which include synthetic compounds, hormones, and enzymes, seem to give promise of halting the growth of certain neoplasms or perhaps even of causing their regression (1). In this chapter, however, only the application of chemotherapy to infections, more specifically to surgical infections, will be discussed. As used currently, chemotherapy in infections includes the use of both the sulfonamides and antibiotic agents. Other terms for these are antimicrobial, anti-infective, antibacterial, and antiviral agents.

HISTORICAL SURVEY

Mercury, used in the sixteenth century in the treatment of syphilis, was probably one of the earliest examples of chemotherapy. During the next century, cinchona bark was found to be curative against malaria even though the active principle *quinine* was not discovered until much later. Aside from the local use of carbolic acid spray by Lister in 1867, there was no further advance for nearly three centuries until 1907 when Paul Ehrlich found that the synthetic drug *atoxyl* was effective against the trypanosome, which was known to cause sleeping sickness. Three years later Ehrlich revolutionized the treatment of syphilis with "606" or salvarsan. Others followed in this path with the discovery of the use of antimony compounds in kala-azar, and emetine in amoebic dysentery. Ehrlich was probably the first to use the term *chemotherapy*. His quest involved studies on thousands of drugs, tested first in the test tube to see if they stained and therefore killed bacteria, later for toxicity in the living organism. This involved systemic empiricism which is still used, but the basic concept is now quite different, as discussed below.

Three decades were to pass before the start, 20 years ago, of the present spectacular era in chemotherapy, which began with the use of sulfanilamide. This new development was really revolutionary because it was based on an entirely new concept which was not obvious at first. Previously, research had been directed at finding drugs which would destroy bacteria in the test tube and yet be nontoxic to the patient's cells; hence the terms germicide and bactericide. The effects of the new chemotherapeutic drugs may be bacteriostatic, bactericidal, or both. The majority of the agents are bacteriostatic, causing interference with the normal metabolism of the various bacteria and thus inhibiting their growth and multiplication. Under these conditions the body's normal defense mechanisms are then able to dispose of the infecting microorganisms.

The first new look in chemotherapy came about quite by accident. Gerhard Domagk, in Germany, in 1935 noted that rats marked with a red dye, Prontosil, did not develop streptococcal infections as did those not so marked. Upon further study he found that this dye was indeed effective in the living animal. The following year this same chemical was shown, by Colebrook and Kenny in England, to be successful in the treatment of human streptococcal puerperal infections.

an increase rather than a decrease in the incidence of civilian wound infections, particularly when the drug was used in conjunction with primary closure of contaminated wounds. It took a long time to relearn the lesson that aseptic technic, meticulous and time-consuming cleanliness, and the mechanical removal of contamination, of dead tissue, and of foreign bodies were important principles in the treatment of such wounds. They are still potent factors in the prevention of infection, without which per primam healing cannot be expected.

In the consideration of the *history of systemic chemotherapy in surgery* we should recall that when the dramatic benefits of the newer chemotherapeutic agents were first called to our attention it appeared that many operations formerly considered necessary to control surgical infections might prove to be unnecessary. This was, in fact, true in such cases as acute osteomyelitis, mastoiditis, and carbuncle (see below). It proved untrue, however, in other surgical infections, notably peritonitis from acute appendicitis. Sulfanilamide alone was first tried in the treatment of acute appendicitis, and other forms of chemotherapy are still erroneously employed in this disease with the idea of avoiding the need for operation. It was soon learned by sad experience that chemotherapy as the sole method of therapy had a real potential danger in this disease because it had no certain influence on the perforation of the infected appendix, which so readily leads to peritonitis. Worse than this, however, the clinical manifestations of infection were masked by this drug, which engendered a false sense of security. Thus peritonitis progressed until it was often too late for the surgeon to remove the cause of the infection and thus prevent a fatal outcome. While chemotherapy has helped to reduce the mortality in perforative appendicitis (see below), it does so only as an adjunct to operative removal of the anatomical cause of the infection.

The advent of chemotherapy influenced surgery in another beneficial way, by permitting the advance of technical frontiers previously feared but now known to be safe. The actual and partly psychologic aid of the new agents gave surgeons courage to use certain technics which reduced complications and eventually led to more rapid convalescence. Three examples may be cited: 1, the early and more radical secondary suture of accidental wounds, discussed in more detail in Chapter 14; 2, the more frequent use of primary intestinal anastomosis, especially of the colon; and 3, the elimination of drainage in many cases of diffuse peritonitis due to perforation of the appendix.

GENERAL PRINCIPLES OF CHEMOTHERAPY

As a result of this historical experience and for other reasons there is now general agreement as to certain principles governing chemotherapy in surgery. The first principle may be expressed by stating that chemotherapy is always an adjunct and not a cure-all in the treatment of the patient. Operation may be and often is urgent on the basis of the indications in each individual case. A second principle applies to the timing of operation in suspected perforative lesions of the gastrointestinal tract, as already discussed above, and in certain deeply seated established infections. Because chemotherapy may obscure the clinical manifestations both local and systemic, operation should be carefully planned in relation to the chemotherapeutic program. In the case of acute appendicitis, chemotherapy should be started after and not before the decision to operate has been made, but well before the anesthetic is given. Timing in operations upon patients with established infections is a little more difficult and is discussed below. A third principle deals with the question of dosage and is based on the idea that a sufficiently large amount of the drug should be given initially and only for as long as necessary, in contrast to the policy of starting with a small dose and increasing it if progress is unsatisfactory. An adequately large dose used for a relatively short period of time reduces the danger of saprophytic bacteria becoming pathogens, and decreases the incidence of acquired resistance by the causative agent to the antibiotics. This principle is especially applicable when operation is indicated for reasons already mentioned. A fourth principle is the importance of early chemotherapy in localized areas of cellulitis in order to avoid suppuration. In such a case,

which led to the discovery, in 1944, of streptomycin and eventually to many other similar antibiotics. In common with the sulfonamides, all of these new substances had the property of altering the metabolism of the invading bacteria so as to prevent them from growing or make them relatively nonvirulent. The rapid historic developments in antibiotics up to 1948 are well described in a monograph by Work and Work (4). The most recent summary of antibiotic therapy is that by Welch and Lewis (5). Much data can also be found in a monograph edited by Dubos (6).

At the present time, the number of antibiotics has increased so tremendously that a dictionary of antibiosis is now available (7). Some of the antibiotics will be discussed in detail later. Two features of this great advance should first be mentioned. In the beginning, each of the new agents seemed to be effective against an increasing number of bacteria, or as commonly expressed, each covered a widening spectrum of bacterial invaders. Unfortunately, a second feature was soon noted; the increasing resistance of bacteria to antibiotics, a phenomenon which naturally greatly decreased and is continuing to further decrease their usefulness. For example, the sensitivity of various staphylococci to penicillin has fallen from 93 to 95 per cent in 1943 to a low level of 12 to 57 per cent in varying reports since then. A similar phenomenon has been observed for the coliform group toward the broad spectrum antibiotics and for the *M. tuberculosis* toward streptomycin (8). This change has been of special importance in the case of the staphylococcus, which has now become so much more virulent that actual epidemics of staphylococcus infection have been described, many of which are unaffected by penicillin or, indeed, by other agents. This is particularly true in the case of personnel and patients living in hospitals, so much so in fact that the term "hospital staphylococcus" has been used to describe this newly developed antibiotic-resistant strain (9, 10). At the same time, more and more patients now show allergic and other reactions to penicillin than ever before, despite the fact that the present product is of greater purity (see below).

The history of local chemotherapy dates from the carbolic acid spray dressings of Lister, through Dakin's solution of World War I, and the local use of sulfanilamide powder in World War II. Though not directly a chemotherapeutic agent, the various proteolytic enzymes (streptokinase, streptodornase, trypsin, plasmin) used for irrigation of infected wounds should also be mentioned at this point because they may be of great benefit in promoting healing by removing nitrogenous debris from the wound and thereby discouraging bacterial growth.

The influence of "in vitro" thinking is still profound, despite the change in emphasis from the test tube to the biological approach toward chemotherapy. There is still a deeply ingrained belief, or rather wishful confidence, in the local antibacterial action of any substance that may be placed into a contaminated or infected wound for this purpose. As a result, countless thousands of dollars have been spent and are still being spent in devising many varieties of chemical substances, including the antibiotics, which may be applied locally for purposes of "ridding the wound of bacteria."

Locally applied chemicals are extensively used throughout the world in the present time as in the past. It should be emphasized, however, that despite its real though limited value, there is a basic fallacy in any attempt to sterilize a contaminated or infected wound in this manner. For one thing, the agent can seldom, if ever, reach all of the crevices and angles of the wound to make contact with the contaminating or invading bacteria. Secondly, the chemotherapeutic agents have no influence on necrotic tissues, inadequately drained deep cavities, and foreign bodies, each of which plays an important part in the progress of a wound infection.

In the early days of chemotherapy this fundamental principle was temporarily forgotten, as exemplified by the mistakes which followed the local use of sulfanilamide on the mass casualties resulting from the attack at Pearl Harbor. Surgeons were too quick to believe in the purported magic of the new powder, which was said to prevent all infection by merely dusting it into and onto all contaminated wounds and burns. What happened was that old, established principles were abandoned. As a result, there followed

TABLE 1. Average Daily Dosage for Chemotherapy

(Aided by New and Nonofficial Remedies, by A.M.A. Council on Pharmacy and Chemistry, J. B. Lippincott, 1957)

Drug	Oral	Parenteral
Sulfadiazine	6–9 gm. (100 mg./kg. initially)	30–50 mg./kg. × 3 or 4 after 100 mg./kg. initially not to exceed 5 gm., as 5% solution IV or as 0.3–0.7% solution subcutaneously
Sulfamerazine	3 gm. (3 or 4 gm. initially)	
Sulfamethazine	4 gm. (100 mg./kg. initially)	
Triple sulfa (equal parts of above)	4 gm. (3 or 4 gm. initially)	
Succinylsulfathiazole (sulfasuxidine)	250 mg./kg. × 6 after same dose initially	
Phthalylsulfathiazole (sulfathalidine)	50–100 mg./kg. × 3–6—not to exceed 8 gm.	
Penicillin		300,000 units (IM or IV) × 3 (or more)
Streptomycin	2 gm.	1 to 4 gm. (IV or IM)
Chlortetracycline HCl (aureomycin)	250 mg. × 4	20 to 25 mg./kg. IV, buffered with sodium glycinate
Oxytetracycline HCl (terramycin)	250 to 500 mg. × 4–8	500 to 1,000 mg. IV
Tetracycline HCl (achromycin)	Same as chlortetracycline	Same
Chloramphenicol (chloromycetin)	250 to 500 mg./kg. × 8 after 50 to 70 mg. initially	1 gm. IM × 2 or 3
Erythromycin (ilatycin)	200 to 500 mg. × 4	250 mg × 4 IV as glucoheptonate (also as lactobionate)
Neomycin	1 gm. per hr. for 4 doses then 1 gm. every 4 hrs. for 24–72 hrs.	Maximum 1 gm. in saline intraperitoneally
Polymyxin B	75–100 mg. × 4	1.5 to 2.5 mg./kg. IM (maximum 200 mg.)
Novobiocin (albamycin)	1,000,000 units × 4	
Viomycin		500 mg. × 2 every third day

often be had within 12 to 24 hours (11). There are, of course, many pitfalls in the collection of material for bacterial diagnosis as already discussed on page 71. These must be avoided, particularly in testing for bacterial sensitivity to antibiotics for mixed infections at least, lest data on secondary invaders be collected and the invading organisms be missed.

In Table 1 the more important drugs are listed along with their oral and parenteral dosage as used in surgical infections. Their application clinically will be discussed under the heading of therapy.

operation may be avoided and the progress of the infection may be reversed, resulting in its spontaneous resolution. The history of acute osteomyelitis illustrates this point very well, and is, therefore, described in detail.

The lifesaving action of penicillin when first used in acute osteomyelitis was almost matched by its equally dramatic influence on the local lesions. Before the days of penicillin, the initial radiologic changes in the bone could be seen in this disease about 5 to 7 days after its onset. Suppuration, long disability, and sequestration followed. The beneficial effects of penicillin upon the bone lesion were first shown when the expected radiologic changes were seen not in a week, but only after two or more weeks. Moreover, the changes were slight, frequently did not progress, or disappeared. It was soon evident that if treatment were started early enough, penicillin had the power to completely prevent sequestration. Even when penicillin was given late, it so inhibited the infection that occasionally a definite demonstrable sequestrum seemed to act as a bone graft and became incorporated into the living bone with little or no surgical procedure. Finally it was found that if penicillin was given in adequate doses within 24 hours of onset there were no radiologic evidences whatever.

To the younger surgeon, failure to show radiologic signs raised the question as to whether the patient actually had osteomyelitis. Such doubts did not occur to experienced surgeons who, in the past, had seen many of these children with characteristic local manifestations go on to show typical radiologic bone changes. Thus it became apparent that, with the early use of penicillin, the value of x-ray in the diagnosis was greatly reduced or even lost. At the present time, therefore, a diagnosis of acute osteomyelitis must be made at the bedside on the basis of the clinical picture and without any corroborating radiologic signs.

The effect on mortality was even more dramatic. Figures at the St. Louis Children's Hospital revealed a death rate from staphylococcic osteomyelitis of 10 to 15 per cent in the years before 1936. During the period of sulfonamide therapy, 1937 to 1942, mortality was still high, 10 deaths among 48 cases. After the introduction of penicillin in 1943 the only two deaths occurred in the first years when the drug was scarce and the dose was inadequate. For example, a child two years old was given a total of only 18,000 units of penicillin. We had not yet learned how effective and important large doses were, and an attempt was made, therefore, to spread the small amount available among as many patients as possible. There have been no deaths since 1944.

SELECTION OF CHEMOTHERAPEUTIC AGENTS

With the vast array of agents now available, it is often difficult to choose the most effective. The trend to utilize an antibiotic having the widest coverage, or even a combination of them, is justified in mixed infection when "combined chemotherapy" is an established practice. The use of more than one agent for the synergistic effect is also justified in certain infections. A popular example is the use of penicillin to destroy the cocci and streptomycin to counteract the gram-negative organisms. In many cases, however, this attitude toward "antibiotics" is based upon the "shotgun" principle of therapy, a principle which in general should be avoided. Selection of a specific antibiotic based upon knowledge of the invading organism or organisms is not only theoretically desirable, but practically feasible in many cases. Only in this way can predictable results be expected, based upon the use of specific agents known to combat specific infections. Such information is sometimes available at once as part of the clinical diagnosis. For example, an acute spreading cellulitis is nearly always due to the hemolytic streptococcus; acute mastitis, furunculosis, carbuncle, and perinephric abscess to the staphylococcus; acute perforative appendicitis to mixed bacterial flora involving the coliform group, streptococci, clostridia, bacteroides, or anaerobic streptococci. Selection of the proper antibiotic can now be made more specific when the organism or organisms are identified from the blood or from the infected tissue or purulent material itself. "In vitro" sensitivity tests of each bacterium against a series of antibiotics can be readily measured. This laboratory procedure is useful when properly done, and the results can

perhaps account for the fact that most of them have proved too toxic for systemic use. *Bacitracin* may, however, be employed as a local agent in specific instances.

More recently *Polymyxin B*, originally called aerosporin, proved of surgical importance as a most effective agent against the *Pseudomonas aeruginosa* (3). However, even this drug must be given with great care and with a local anesthetic agent such as procaine to minimize the pain at the site of the injection.

In the following discussion the various agents will be mentioned first in terms of their prophylactic value and second, in terms of definitive therapy in established infections. It will be apparent, however, that this classification is not always exact and that considerable overlapping will occur in specific types of disease. Untoward reactions will be discussed separately.

PROPHYLACTIC THERAPY

The *local* use of chemotherapy for the prevention of infection in contaminated wounds still has a place whenever considerable delay may occur in definitive therapy. Even war wounds are now handled so promptly after they are sustained that much of the advantage described for local chemotherapy early in World War II has lessened considerably. Nevertheless, any contaminated wound may be helped by local chemotherapy if periods beyond 8 to 12 hours will have lapsed before cleansing and débridement can be carried out, particularly if systemic administration is difficult or impossible. Prophylactic local chemotherapy in wounds has now been largely replaced by systemic administration, for in this way the invading organism can be attacked from the body side which, in general, is much more effective and certain. Indeed, much of the benefit derived from a soluble agent placed in the wound followed its absorption therefrom and the resultant systemic effect. Surgeons are beginning to escape from the test tube concept of contaminated wounds and seem ready to discard or to rely less upon local chemotherapy for the prevention of infection. For systemic chemotherapy, slowly absorbed procaine penicillin G, with or without added streptomycin, was extensively employed in the Korean conflict. However, since absorption was shown to be irregular or even impaired in shock, crystalline penicillin was recommended and was given as an intravenous injection.

The *systemic* use of chemotherapy for the prophylaxis of infection in clean wounds made in the operating room reached its apogee soon after penicillin became available in large quantities and at a moderate cost. This "miracle" drug was soon given after practically every surgical procedure involving an incision or a general anesthetic, starting usually in the immediate postoperative period and often continued until the patient left the hospital. Its routine prophylactic use is now following an ebb course because surgeons are beginning to realize that their blind reliance on it has produced many hazards, as well discussed by Altemeier (8).

For systemic prophylaxis, penicillin and streptomycin are often given simultaneously when contamination has been sustained (e.g., resection of the colon). Originally, the penicillin had to be given every three or four hours, but by changing the vehicle it need not be injected more than two or three times per day (18).

In the case of peritonitis from a perforated appendix, the effect of chemotherapy may be said to be both prophylactic (to prevent further spread of infection during operation) as well as definitive (to combat an established infection). However, since the removal of the source of infection is more important than chemotherapy, the latter can scarcely be called the specific agent for the control of infection as it is, say, in the case of acute osteomyelitis, in which chemotherapy has all but eliminated the need for emergency operation. This does not mean that chemotherapy has not led to a decisive change for the better in peritonitis of appendiceal origin. Mortality from this disease has been cut to less than one-fourth since the advent of chemotherapy, and the morbidity has been all but eliminated. For example, children who were gravely ill with general peritonitis formerly were faced with a mortality above 30 per cent. Such patients can now be operated upon for removal of the appendix, treated with antibiotic therapy, and be ready for discharge from the

Sulfonamides. Although the sulfonamides have little effect on the staphylococcus, their action against streptococcus and against gram-negative organisms is so definite that there is still a place for them, especially since they can be given so readily by mouth and are so inexpensive. The most popular sulfonamides for systemic use are the sulfapyrimadines, i.e., sulfadiazine, sulfamerazine and sulfamethiazine, singly or together. In some infections such as meningitis they are as good as the antibiotics. A recent analysis (12) lists the diseases in which the sulfonamides may be useful, either alone or in combination with the antibiotics. The insoluble sulfonamides are still used for their local action in the gastrointestinal tract but have been somewhat, though not entirely, supplanted by the antibiotics (see below). Research on newer sulfonamides has continued along with extensive investigation in the antibiotic field. One of the most recent and promising of the newer sulfonamides is sulfamethoxypyridazine, which after a single oral dose maintains an effective blood level for over 48 hours and has been followed by no renal complications (13).

Antibiotics. Of all of the various organisms studied, the actinomycetes have yielded the largest number of useful antibiotics. Most of these are tetracyclic, but some are aromatic compounds. All are active against many bacteria, possessing a broad spectrum. All can be given both by mouth and by injection. They are, however, still the most expensive of the antibacterial drugs. When given by mouth most of them are absorbed, thus giving a systemic effect, and also act locally in the gastrointestinal tract to eliminate most of the gastrointestinal bacteria, at least temporarily. In addition they are excreted in the bile and thus also exert an effect in the biliary tract.

Streptomycin (also dihydrostreptomycin), together with penicillin, is moderately effective against mixed infections. It is commonly employed in the treatment of tuberculosis. Mention should be made here of para-amino salicylic acid and of isomers and derivatives of nicotinic acid, such as isoniacid, which have proved of clinical value in the treatment of tuberculosis, particularly when given with streptomycin. Combinations of streptomycin with these agents delay the emergence of resistant strains of the tubercle bacillus and produce better clinical results.

Chlortetracycline (*Aureomycin*), *oxytetracycline* (*Terramycin*), and *chloramphenicol* (*Chloromycetin*) are three of the older antibiotics obtained from actinomycetes. These are called broad-spectrum antibiotics because they are effective against a wide variety of gram-positive organisms (Table 2), as well as the rickettsial, psittacosis, lymphogranuloma, and trachoma group of infections. Unlike the first two, chloramphenicol is an aromatic compound which has been synthesized and is being manufactured for commercial use. It is particularly effective against salmonella and proteus organisms and the *Hemophilus influenzae*. Curiously, few staphylococci have developed resistance to chloramphenicol.

Neomycin has valuable properties in sterilizing the gastrointestinal tract rapidly, often within a period of 24 hours. It is generally considered too toxic for systemic infection, however. It has been used occasionally in the peritoneal cavity as an antibacterial agent in patients with actual or threatened peritonitis (14). Utilized in this manner in large doses, it may produce severe toxic reactions including respiratory arrest.

More recent members of this group are *tetracycline* (achromycin) and *erythromycin*. The latter is of special interest because of its high specificity against staphylococci, which for reasons mentioned above, is particularly important now that penicillin is proving ineffective in more cases (15). *Tetracycline* has been reported (16) as producing much higher blood and tissue levels than oxytetracycline or chlorotetracycline.

Novobrocin (albamycin, cathomycin), another recent entrant into the broad-spectrum field, is particularly effective against the staphylococcus and the proteus organisms (17). The latter is of particular significance in the group of saprophytes which become pathogenic following the use of combined chemotherapy.

Nystatin (Mycostatin) is somewhat effective against the *Candida albicans* (monilia) and apparently against coccidiomycetes.

Antibiotics obtained from soil bacteria, curiously enough, have proved to be polypeptides. This chemical characteristic may

replacement of lost fluids, includes massive, combined, well-chosen antibiotic therapy.

The Production of Delayed Infections by Chemotherapy. One of the unexpected effects of prophylactic chemotherapy has been the postponed or delayed appearance of an infection resulting from contamination, often in an otherwise apparently aseptic and closed incision. Such a delayed infection may be suspected when fever develops as soon as the prophylactic chemotherapy is discontinued. Indeed, it is always important, should chemotherapy be used in this way, to observe the patient for several days, even as long as a week, after the drug has been discontinued. Such delayed infections may be present without fever and be revealed only by swelling of the wound and other local evidences of suppuration. In such cases, the material obtained by separating the affected wound edges should be examined in order to make a bacterial diagnosis and perhaps, if possible, to select a chemotherapeutic agent which is effective for the organisms. The modified chemotherapy should be used in addition to ordinary and simple measures of treatment, particularly the drainage of the abscess. A number of such cases have been studied and critically evaluated (23).

DEFINITIVE THERAPY

The use of chemotherapy as a definitive means of combating established infection shades into its prophylactic use, as already mentioned. Thus, if used sufficiently early during acute cellulitis, many established infections may be stopped in their tracks, so to speak, and thus prevented from producing tissue necrosis and abscess. This not only applies to acute osteomyelitis, as discussed in detail above, but also to acute cellulitis of any type. It is probable, for example, that the therapeutic use of penicillin in the early stages of furunculosis has undoubtedly eliminated the development of many carbuncles.

In most established infections it is desirable, if possible, to obtain some of the purulent material for identification of the organism, as already mentioned above. Thus, unless there is an acute emergency, the selection of or a change to the proper antibiotic agent can be made on the basis of specific information obtained as the result of the identification of the organism and of the results of carefully performed sensitivity tests. When this is impossible, the least that can be done is to determine by smear whether the organism is gram-negative or gram-positive. A most valuable and extensive study of thousands of organisms obtained from surgical infections has been reported by Altemeier and his associates (3) and is summarized in Table 2.

For the treatment of established infections, the sulfonamides cannot be dismissed for reasons already mentioned. However, penicillin and streptomycin still are used extensively and have much to recommend them, especially in patients already confined to the hospital. The various tetracyclic drugs and chloramphenicol are more widely employed, and justifiably so, because they are effective against more organisms and thus applicable when there is a mixed infection. This is not only true in infections originating from the

TABLE 2. Susceptibility Within Bacterial Species

(From Altemeier et al. (3), courtesy of the J.A.M.A.)

	Number of Strains/Susceptibility, Per Cent			
	Penicillin	Chlortetracycline	Chloramphenicol	Oxytetracycline
Hemolytic micrococcus (*Staphylococcus*) *aureus*	768/57	752/67	776/74	729/72
Nonhemolytic micrococcus (*Staphylococcus*) *aureus*	415/57	405/63	418/89	363/69
Hemolytic streptococcus	197/86	192/98	179/97	179/92
Nonhemolytic streptococcus	141/63	132/74	141/92	109/83
Streptococcus viridans	50/80	50/52	58/100	42/95
Escherichia coli	478/0	575/20	586/94	535/92
Proteus group	506/0	488/17	501/79	431/27
Aerobacter aerogenes	170/0	193/72	173/91	153/86
Aerobacter fecalis	21/0	19/68	19/95	14/79

hospital in a little more than the period of time required for an interval appendectomy. This effect, however, cannot be achieved unless the principles outlined are observed, including chemotherapeutic saturation of the tissues of the body before the anesthetic is given and the incision is made.

Prophylactic chemotherapy is indicated in most patients with extensive accidental wounds, including severe burns, seen in civilian as well as in military practice. It is also important in elective operations through contaminated areas such as the gastrointestinal, respiratory (including the oral and pharyngeal cavities), and genitourinary tracts. The latter group is especially important in view of the susceptibility of elderly patients to coliform bacteria after genitourinary operations, as noted in a study of 65 cases (19). This is also true of operations in elderly patients with incipient or actual respiratory disease. In patients of this kind, in whom a postoperative pneumonia is feared, the administration of the antibiotic should really begin before the operation so that the alveolar fluid will contain a therapeutic concentration of the drug during the anesthesia when exudation may begin. It is assumed that the fluid escaping into the alveoli under these conditions will be less likely to lead to postoperative infection and atelectasis if it contains a high concentration of the therapeutic antibiotic. However, the possibility of pneumonitis produced by resistant bacteria under these conditions must be kept in mind.

In an urgent operation performed on any patient in whom there is an unrelated infection elsewhere, such as furuncle or tonsillitis, prophylactic chemotherapy may also be indicated. In patients with pre-existing valvular heart disease, chemotherapy should also be started before operations on the oropharyngeal tract to prevent the development of vegetative endocarditis.

The prophylactic use of various chemotherapeutic agents on gastrointestinal flora in preparation for operation on the colon is of special interest. In the absence of intestinal obstruction and when sufficient time is available, the insoluble sulfonamides, particularly sulfathalidine, are used and will produce temporarily an almost bacteria-free stool in 3 to 5 days. Neomycin achieves a similar effect in 24 to 72 hours, being also scarcely absorbed from the gastrointestinal tract. Streptomycin can be used in the same way. The tetracyclines and chloramphenicol will also produce gastrointestinal antisepsis in three days or less, but, being soluble, will lead to tissue saturation as well. Chemotherapy and evacuation of the large bowel by catharsis or enema should be carefully timed. In the presence of intestinal obstruction or in emergency operations, neomycin is preferable because of its rapid action. The many factors involved in gastrointestinal antisepsis in surgical patients have been critically analyzed by Poth (20).

Prophylactic therapy may also be indicated in two other conditions as the result of recent investigations. The first concerns strangulated intestinal obstruction, where the action of intestinal bacteria on a damaged bowel is now known to produce toxins which are an important factor in the development of peripheral circulatory impairment (21). It is thus important to inhibit or stop this action with adequate chemotherapy before operation in any patient suspected of having intestinal strangulation. Here, too, chemotherapy must not be delayed, but must always be combined with prompt operative intervention.

Chemotherapy is also important in the management of patients in shock associated with severe infections. This condition is generally referred to as "septic shock" and its cause is not necessarily associated with the loss of blood or fluid. This particular type of shock occurring during an infection has been studied in detail by Altemeier and Cole (22), who pointed out several of its diagnostic characteristics. Septic shock should be suspected whenever there is a sudden development of unanticipated circulatory collapse in any patient with fever, particularly when there has been no evident cause such as loss of fluid or hemorrhage. Chemotherapy itself may mask localizing and even systemic manifestations and thus engender a false sense of security in the face of a serious invasion. Other manifestations include failure of shock to respond to the usual methods of replacement therapy, a high leukocyte count above 20,000, and the presence of petechiae, unexplained delirium and ileus. The treatment, in addition to the usual measures aimed at

different observers, but an incidence has been reported as high as 16 per cent. The tremendous increase in the use of penicillin (in 1952, 350 tons were sold) has probably been largely responsible for the increased rate of untoward reactions. The popularity of the longer-acting procaine penicillin has multiplied the hazard since procaine itself has antigenic properties. It is probable that 50 per cent or more of the population of this country has received penicillin at one time or another, unfortunately in the majority of cases with insufficient indications. Since the proportion is constantly increasing, greater numbers of people are becoming sensitive to penicillin. In each patient, therefore, one should specifically ask for a history of penicillin sensitivity, or even whether the patient has previously received this agent. Moreover, anyone with known allergic disease, such as asthma, should be considered to be sensitive until proved otherwise.

In the surgical patient, untoward systemic reactions, particularly fever, are often of great practical importance. Since fever may also be due to the infection for which chemotherapy is being used, the surgeon is often misled as to the need for continuing the drug. When fever persists after other signs of infection seem under control, it is often worthwhile stopping the penicillin, sulfonamide, or other agent to see if the patient will become afebrile. If this occurs, it is likely that the fever has indeed been allergic in nature. A "serum sickness" pattern, which includes the triad of fever, arthralgia, and urticaria (sometimes lymphadenopathy), is, of course, diagnostic of an allergic reaction. Unfortunately, this complication may persist for weeks or months after the drug, including streptomycin and the sulfonamides, is discontinued.

Prevention of untoward reactions is, of course, far better than cure. For this reason penicillin should not be used when the patient is known to be, or likely to be, sensitive thereto, particularly when a suggestive history is obtained, as mentioned above. When allergic manifestations actually occur, changing to another antibiotic is usually indicated, although in mild cases epinephrine or antihistaminic drugs may be used. The more serious manifestations call for cortisone therapy.

Streptomycin. Although used extensively and, in the case of tuberculosis, for long periods of time, streptomycin does have a specific effect of partial or complete paralysis on the eighth nerve in a few patients. This hazard is probably less when dihydrostreptomycin is used. The development of tinnitus or other signs referable to the function of either branch of this nerve should always call for discontinuance of streptomycin and the substitution of some other antibiotic.

Chlortetracyline (Aureomycin), Oxytetracycline (Terramycin), and Tetracycline (Achromycin). These are probably the safest of the antibiotics in terms of provoking allergic reactions, yet they are apt to produce gastrointestinal disturbances, especially diarrhea.

The use of these broad-spectrum antibiotics has led to other more severe gastrointestinal difficulties because of the overgrowth of many microorganisms such as the hemolytic staphylococcus, monilia, the *B. pyocyaneus* (*Pseudomonas aeruginosa*), and *Proteus vulgaris* (*B. proteus*). When the other fecal bacteria have been eliminated by means of chemotherapy, these microorganisms may grow unopposed and assume pathogenic properties even to the production of serious pseudomembranous enterocolitis (26). This mechanism must always be reckoned with whenever broad-spectrum chemotherapy is used in the gastrointestinal tract. The recommended management includes the discontinuation of the antibiotics in use and the administration of other agents known to be effective against the offending organism. When the staphylococcus is responsible, which it often is, erythromycin, chloramphenicol, or other agents may be used, as shown by sensitivity tests, if possible. In other instances, other chemotherapeutic agents may be employed, especially polymyxin-B, and mycostatin against the *B. pyocyaneus* (*Pseudomonas aeruginosa*) and monilia respectively.

Chloramphenicol (Chloromycetin). This is the first naturally occurring antibiotic containing a benzine ring with a free nitro group. It was thus expected to be more antigenic than other antibiotics obtained from the growth of actinomycetes. While a number of cases of agranulocytosis and aplastic anemia were reported early, later experience seems to indicate that the drug is as safe as the other broad-spectrum agents. It is now being used

gastrointestinal tract, but also in external wounds which have been secondarily invaded by many contaminating organisms. While chemotherapy may be all that is necessary in a few established infections, such operative procedures as incision and drainage of abscesses, closure of perforations, removal of necrotic tissue and foreign bodies, plastic repair or closure of wounds, skin grafting, and closure of fistulas or anastomoses are usually necessary and must be carried out at an appropriate time. The common mistake is to wait too long for such operations, which should really be carried out as soon as possible after the infection is localized or has been brought under control, as the case may be. Delay often permits sensitive organisms to develop resistance to the agent and saprophytes to become pathogenic.

UNTOWARD REACTIONS

The indiscrimate use of antibiotics, which started soon after their introduction and unfortunately still continues, is undoubtedly responsible for the large number of unfavorable reactions now encountered. It cannot be emphasized too strongly that any drug, including antibiotics, should be used only when definitely indicated. The complacent, uncritical administration of any material to a healthy or sick patient imposes definite responsibilities upon the physician and surgeon (24). This philosophy has already been discussed in the section on blood transfusions. This does not mean that these effective chemotherapeutic agents should be withheld when they are really needed, but it does mean that they should not be employed unless there is a definite indication. Moreover, the dosage should be adequate but not excessive, and should not be continued indefinitely after a favorable response has been achieved, or after it has become apparent that such a result cannot be achieved. In the following discussion it will be apparent that many untoward reactions are allergic, due to hypersensitivity of the body to the antigenic action of the drug. This state may be produced by the absorption of small doses of the drug even from an ointment applied locally. An excellent short monograph by Alexander (25) describes the nature and clinical significance of many of such reactions. Much of the following data was culled therefrom. On the other hand, many untoward reactions can be described merely as "toxic" and some due to specific mechanisms which will be described.

Sulfonamides. The sulfonamides have chemical characteristics, such as a benzine ring with the free NH_2 group in the para position, which have long been known to possess haptenic (antigenic) properties. Such drugs tend to produce allergic reactions usually when given for the second time in therapeutic doses after an appropriate interval. Nevertheless, allergic manifestations such as skin eruptions from the sulfonamides are seldom serious and certainly not more frequent than 5 per cent. Sulfanilamide itself was much more likely to produce side effects, but is seldom if ever used at the present time and hence is not discussed. More serious allergic or "toxic" manifestations such as hepatic damage, periarteritis nodosum, and nephrosis, though quite rare, are important because of their high mortality. Fever, though also rare, leads to clinical difficulties similar to those encountered with penicillin, which is discussed below. A specific type of rênal damage associated with sulfa therapy is due to the precipitation of the acetyl derivatives of these drugs in the renal tubules. Fortunately this problem can be readily solved because the acetyl derivative of each of the sulfonamides is different and independent of the others. Thus the likelihood of precipitation can be reduced by giving a much smaller dose of each of three or more different, selected sulfonamides and by maintaining an adequate fluid intake and urinary output. Fortunately their therapeutic action and blood levels are additive.

Penicillin. When first introduced, penicillin, even though relatively impure as compared with present products, seldom produced an untoward reaction, even when given in daily doses up to several million units a day. However, by 1951, six fatalities due to anaphylactic shock, the most severe manifestation of allergy, were reported. Many more have occurred since then, in fact with increasing and alarming frequency. Moreover, the incidence of the more common allergic skin eruptions, such as erythema and urticaria, though fortunately seldom of clinical importance, has been rising sharply. The figure varies with

6

ACUTE SURGICAL INFECTIONS

Surgeons have long been arbiters in the management of those infections arising as a complication of injury or requiring surgical incision, usually for the drainage of pus, as a feature of management. This is the background for the identification of "surgical" infections; and this chapter is largely concerned with the features and basic principles of pyogenic infection and suppuration.

Shortly after the introduction of sulfonamides and, more especially, penicillin, it was apparent that the gravity of surgical infections had been remarkably and favorably decreased. This remains true for those infections for which *bactericidal* drugs are available, as in the case of the hemolytic streptococcus. On the other hand, there has developed an unstable ecology as regards those bacterial pathogens originally susceptible to drugs that were chiefly *bacteriostatic.* Drug-resistant staphylococci, *Proteus vulgaris* (*B. proteus*), and pseudomonas (pyocyaneus), initially identified in the course of inadequately treated infections, are now being recognized as primary pathogens or as the responsible agents in hospital epidemics of wound suppuration (1). Although antibacterial therapy has revolutionized the technics of management of infections in general, the complexities and final impact of drug treatment have not yet been fully evaluated. There has been no change in the early manifestations of a potentially serious infection or in the basic principles of wound management or surgical drainage of pus. It is recognized that antibacterial therapy may mask the systemic manifestations while the local lesion progresses, and it is axiomatic that chemotherapy cannot obviate the necessity for the surgical evacuation of pus or the excision of tissue devitalized by injury or sepsis. This often creates a dilemma calling for mature judgment on the part of the surgeon. Some abscesses may be treated primarily by incision and drainage without chemotherapy, whereas surgical manipulation of other abscesses may precipitate bacteremia and demand chemotherapy to prevent the development of metastatic abscesses. There are other complications of antibacterial therapy apart from toxic or allergic reactions. Alteration of the normal body flora may permit the overgrowth of yeasts or locally necrotizing saprophytes. Most of these considerations are presented in more detail in the chapter on chemotherapy, but it should be remembered that they apply to the suppurative infections discussed here.

PATHOGENESIS

It is probably true that most primary surgical infections are due to pyogenic cocci, either the beta hemolytic streptococcus or the coagulase-positive micrococcus (staphylococcus). These organisms gain entry to the body through sweat glands, hair follicles, or wounds of the skin or mucous membrane. Once the bacteria have penetrated the protective integument, the subsequent course of events is determined by the virulence of the bacteria, the resistance of the host, and the size of the inoculum (Koch's postulates). For the pyogenic cocci, the somewhat nebulous factor of virulence may be manifest in terms of intense local necrosis of tissue, erysipelas or scarlet fever, or rapidly invasive spread through previously normal tissues. These

more and more, especially since it is effective against a greater number of organisms than other agents (see Table 2), and thus it is less likely to permit saprophytes to become pathogenic. Many of the salmonella group, especially *S. typhosa*, are more sensitive to chloramphenicol than to the other tetracyclic antibiotics. It is also more effective in meningitis than other agents with the possible exception of sulfonamides.

Neomycin. Though not in use very long, neomycin has thus far shown no allergic manifestations. Its rapid action against fecal organisms probably accounts for its relative freedom from the untoward effects of aureomycin and terramycin mentioned above.

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Fig. 1. Acute cellulitis of the right orbit which subsided spontaneously with conservative care. A, at the onset of the swelling; B, nine days later. The primary cause of the cellulitis was a right antral infection which was drained intranasally.

Cellulitis or bacterial *inflammation* consists of local manifestations which are similar to those of nonbacterial inflammation as already described, but so much more pronounced and severe that seldom is there any difficulty in differentiating the two. Subjectively, the patient will usually complain of pain, redness, swelling, and disability. The pain is usually more severe in such sensitive tissue as at the tips of the fingers and such sites as the thick skin at the back of the neck, where swelling results in rapid increase of tension. In such lax tissues as those of the face, pain is apt to be less severe but swelling more evident. Often there is also a throbbing which, with the pain, is aggravated by a dependent position of the inflamed part.

On inspection one sees first the swelling and redness and may feel the heat radiating from the area, all caused by the hyperemia and increased blood flow and exudation. The *redness* is of a fiery color, most intense at the portal of entry, and fading off gradually into normal surrounding skin. The *swelling* often coincides with the redness. Swelling well beyond the area of cellulitis, not red or tender, is due to edema and is observed especially in infections of the hand and face. Should the swelling be so intense as to impair the arterial supply, the part becomes blanched and eventually necrotic. On palpation one can demonstrate *tenderness;* i.e., induced pain or pain elicited on pressure. Such palpation may be justified in order to detect *point tenderness,* which often reveals the probable location of a deep infection, that as yet has produced no changes on the surface of the skin, or which determines the probable site of suppuration in diffuse cellulitis.

Lymphangitis. The lymphatics are invaded early in the course of an invasive infection (Fig. 2). If the channels themselves become inflamed they are evident clinically as red streaks extending toward the regional lymph nodes. Such red streaks are spoken of as tubular *lymphangitis.* Similar involvement of the more superficial lymphatics of the skin may be apparent as a network of red streaks and is known as reticular *lymphangitis.* These lymphatics are tender and the local swelling may be outlined by palpation after application of an ointment to the skin to reduce tactile friction.

Lymphadenitis. The regional lymph nodes are almost always involved in the course of an infection and become palpably enlarged.

manifestations reflect the variable biologic activities of these cocci and require further explanation.

1. *The locally necrotizing action* is due to proteolytic enzymes capable of destroying tissue. The most important of these is collagenase, usually identified in the laboratory by gelatin liquefaction. It is these enzymes that break down tissue to the essential metabolites necessary for bacterial multiplication within the body. Inasmuch as devitalized tissue is generally more vulnerable than living tissue to such proteolysis, the presence of dead tissue favors a more rapid growth of bacteria and assures a more severe infection. It is sometimes forgotten that Pasteur's initial interest in bacteria related to a study of these enzymes and that he defined aerobic proteolysis as fermentation and anaerobic proteolysis as putrefaction. The foul odor of intermediary amides and amines identifies anaerobic proteolysis and distinguishes it from aerobic proteolysis wherein protein is reduced to odorless carbon dioxide, nitrogen, and water. The enzyme systems of the pyogenic cocci are aerobic and especially effective against such collagen-rich tissues as skin, fascia, and tendon to produce liquefaction (suppuration).

2. *The erysipelas or scarlet fever* reaction is due to the production of erythrogenic exotoxin. This toxin is associated primarily with the hemolytic streptococcus, but antigenically indistinguishable erythrogenic toxin is also produced by the staphylococcus. The erythrogenic toxin produces a scarlatiniform rash and sustained fever. When the primary infection is extrapharyngeal and the rash is diffuse, the term "surgical scarlet fever" may be applied. For localized erythemas without cutaneous pigmentation (as demonstrated by complete blanching with pressure applied by a glass slide) and in direct continuity with the local infection, the term "erysipelas" is applicable. The presence of scarlatina or erysipelas is important primarily because the erythrogenic toxin enhances the tissue invasiveness of the pyogenic cocci.

3. *Tissue invasiveness* is dependent upon the capacity of bacteria to invade and spread through living tissues; it is a complex and still incompletely understood phenomenon. The usual response to the injection of such a locally necrotizing substance as turpentine is the process of inflammatory fixation with characteristics of capillary and lymphatic thrombosis around the area of tissue destruction. In the case of the pyogenic cocci, this response is altered. The beta hemolytic streptococci produce a fibrinolysin capable of activating plasminogen to plasmin and promoting dissolution of the plasma thrombus within the lymphatics and allowing the bacteria access to the lymph stream. The staphylococci, on the other hand, appear to intensify the thrombotic process with the result that septic emboli become blood-borne to create metastatic abscesses. Both of these processes intensify the extent and gravity of the local lesion and foster bacterial invasion of the blood stream. This latter complication is known as *bacteremia,* but it is usually reserved in clinical usage for relatively asymptomatic phases of blood-stream invasion. Symptomatic bacteremia (staphylococcemia, streptococcemia) is known as *septicemia,* a word introduced before the discovery of bacteria to identify an experimental disease produced in healthy sheep by injecting them with the blood of animals dying from anthrax. The term *pyemia* is usually reserved for bacteremias of great intensity complicating multiple metastatic abscesses. The lay term is "blood poisoning."

The local and systemic effects of acute surgical infections, including paths of extension, general principles of treatment, and prognosis will be described in that order. The deeper and more regional infections are discussed elsewhere under each specific region or system.

THE LOCAL LESION

Cellulitis. Bacterial invasion at the portal of entry usually produces an area of inflammation, called "cellulitis" (Fig. 1). This is to be distinguished from suppuration, or the formation of pus, which often but not always follows. The distinction between cellulitis and suppuration is important therapeutically because any incision into an area of cellulitis is rarely of value when no pus is present and may actually lead to *dangerous spread* of the infection. Conversely, when pus is present, incision and drainage should, with few exceptions, be promptly carried out.



Fig. 3. The use of two fingers in eliciting fluctuation in a swelling containing fluid. (From Homans. Textbook of Surgery, Charles C Thomas.)

tenderness is an important sign of suppuration when fluctuation is difficult to elicit; e.g., in many infections of the hand and in very small areas of inflammation where it is mechanically impossible to test for fluctuation. In such cases, the gradual narrowing of the zone of tenderness on successive examinations may be of decisive importance as an indication that pus has formed. Point tenderness is also valuable in such deep infections as those of the ischiorectal space or the deep tissue of the thigh or back. *Aspiration* may be advisable in detecting pus in large abscesses, especially when the depth or location of the lesion makes fluctuation or point tenderness difficult to elicit. Aspiration may also be used in other situations where questionable fluctuation exists or cannot be detected; e.g., in empyema thoracis and pyogenic arthritis. If the pus is thick, aspiration may fail unless a large-bore needle is used. Obviously aspiration is contraindicated when it may result in injury to vital or important adjacent structures.

TYPES OF SUPPURATION

Suppuration may take a variety of forms. A few of the types occurring on the surface of the body are described under the following headings:

Simple Abscess. These infections usually follow puncture wounds of the skin, but the initial injury may have been so trivial as to be forgotten. Abscesses in the axilla, groin, and neck are commonly due to suppurative lymphadenitis; in the upper part of the neck dental infections are commonly the cause of abscesses (Fig. 4). Incisional treatment for drainage has already been outlined.

Furuncle. The common boil has a definite anatomic location in the hair follicle and is always caused by the staphylococcus (Fig. 5). It is not always clear how and why this normal inhabitant of the skin suddenly invades the wall of the follicle. Patients with diabetes or Cushing's syndrome are especially subject to furunculosis. The sweat, which normally contains complex fatty acids, is usually bactericidal, but this quality may be lost without apparent explanation or in consequence of profuse diaphoresis. This latter effect is commonly used to explain the summer prevalence of furunculosis.

The initial symptom of a furuncle is pruritus, suggesting an insect bite. Once the staphylococci get a foothold, the process extends beyond the wall of the follicle as an area of cellulitis, which quickly softens into an abscess. The demarcated and necrotic remnant of the follicle in the center may resist digestion and remain as a stout plug, called the core, requiring extrusion or removal. In small furuncles, seen early, suppuration may often be prevented and the infection absorbed by covering the area with thick adhesive plaster. This simple procedure is probably effective because it prevents radiation of heat and thus maintains local hyperemia, and also because it insures local rest and prevents further irritation by clothing or the patient's fingers.

Recurrent furuncles, or *furunculosis,* were often the despair of patient and physician alike. Although not always successful, the use of anionic skin detergents, rather than soap, re-establishes the bactericidal protection of the skin and should be prescribed. Effective and appropriately selected antibacterial therapy is occasionally necessary. Diabetes

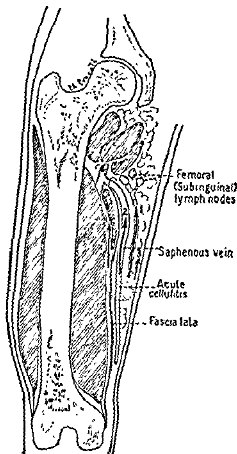


Fig. 2. Three paths of extension of a cellulitis located, for example, on the inner side of the thigh. 1, by lymphatic spread; 2, by venous channels; and 3, by direct extension into the deeper fascial planes or subcutaneously.

When these are tender from rapid swelling, it is presumed they have been invaded by bacteria. It is customary to designate this as septic lymphadenitis. More commonly with staphylococcal infections, the lymph nodes become swollen but not tender and are regarded as inflammatory rather than septic.

Erysipelas. Often in association with streptococcal cellulitis, and occasionally with staphylococcal cellulitis, there is an associated erythematous edema of the skin with palpable borders extending for a considerable distance from the obvious area of cellulitis. This erythema is bright red and blanches completely on pressure, in contradistinction to the bronze erysipelas of anerobic cellulitis. The skin usually desquamates over the involved area during convalescence. These changes are attributable to the erythrogenic toxin and are not usually given special identity in the course of a subsequently suppurative lesion. They may occur, however, without other manifestations, and the infection is then classified as erysipelas. The common erysipelatous lesion about the face, when streptococci enter minor abrasions from the use of spectacles, etc., has a characteristically butterfly appearance. Of more frequent occurrence is the recurrent erysipelas of the lymphedematous extremity, particularly the postphlebitic leg. Skin biopsies almost regularly yield sterile cultures. This has found experimental explanation in the fact that the skin changes follow by some hours the initial invasion by bacteria and the destruction of these bacteria by the host (2). A more detailed discussion of erysipelas will be found *in the following chapter.*

Suppuration (Abscess Formation). Cellulitis may subside uneventfully without, but more frequently with, an appropriately selected and effective antibacterial drug. However, if in the course of the cellulitis there is tissue destruction, its ultimate septic decomposition is assured. Antibacterial therapy rarely, if ever, destroys the bacteria within such a *nidus* of devitalized tissue. The liquefied mass of bacteria, dead leukocytes, exudate, and necrotic tissue is known as pus and the process of liquefaction is known as suppuration. The abscess is identified by the evidence of liquefaction and softening in the center of the lesion. Many other terms are used to identify this process of suppuration and abscess formation; e.g., localization, coming to a head, pointing, walling off, and developing a pyogenic membrane.

The formed abscess develops an internal pressure equivalent to capillary blood pressure and independent of the osmolality of its pus (3). It thus becomes clinically demonstrable by *fluctuation.* Fluctuation is the sensation given to the palpating fingers by any localized collection of fluid, provided it is present under limited tension. One finger compresses the fluid and transmits the impulse to the other, stationary, examining finger (Fig. 3). Lipomas, cysts, or other tumefactions may be so soft as to impart a sense of fluctuation, but cause no difficulty in differentiation in the absence of inflammation. Suppuration may, of course, be evident on mere inspection when the pus has reached the surface and shows through the skin. *Point*

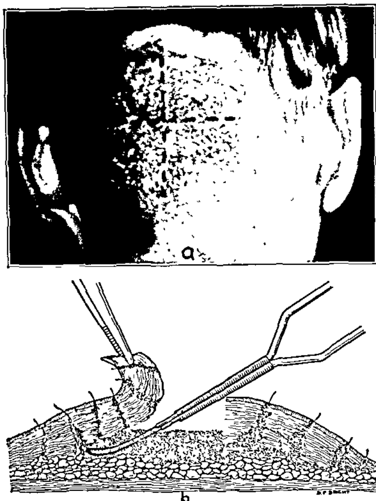


Fig. 6. Carbuncle of the neck: a, the patient is a 55-year-old machinist who first noted a tiny infection of a hair follicle two weeks previously, which spread to its present size. The carbuncle is located higher in the neck in this patient than usual. *The dotted line indicates the lines of incision. Healing was complete* after many weeks; b, diagram of a cross section of a carbuncle showing the multiple "heads" and extension below the derma and involvement of the subcutaneous fat. The proper method of undermining the edges of the skin with a cautery in order to achieve adequate drainage is also indicated. Local and systemic use of penicillin greatly aids healing.

Collar-Button Abscess. Known also as a dumbbell abscess, this infection consists really of two abscesses connected by a tiny communication through some such tough structure as derma or fascia. One of the cavities is superficial and the other is deep. The deep abscess is harder to detect, yet recognition is essential for adequate drainage. Collar-button abscess is especially common in the hand, where a deep palmar abscess may break through a tiny opening in the deep fascia and present as a subcutaneous lesion in the web of the fingers on the dorsal aspect. Persistence of drainage after incision of any superficial abscess should arouse suspicion of a deeper pocket. Such a pocket may often be outlined *radiographically after injection of* a radiopaque fluid.

Carbuncle. A carbuncle may be described as a series of collar-button abscesses whose deeper pockets communicate while the superficial abscesses are separate (Fig. 6). The infection may start as a simple boil, or furuncle, which breaks into and extends along loose areolar and fatty subcutaneous tissue, coming to the surface irregularly along tiny channels described by J. C. Warren as "columnae adiposae." The tough derma in the



Fig. 4. A subcutaneous abscess of the neck. This abscess (under the mandible) resulted from an acute dento-alveolar abscess which ruptured through the tissue about the jaw but did not enter the floor of the mouth or the deep cervical tissue. Incision and drainage were followed by satisfactory healing.



A



B

Fig. 5. A, large furuncle of the face near the hair line; B, an acute *furuncle of three days' duration which, because of its location, represents a dangerous type of infection. Rest and local heat were applied* with spontaneous drainage and rapid healing. Incision in this type of infection is hazardous (see Fig. 8).

should always be *suspected* and appropriately treated if diagnosed.

To be distinguished from furunculosis is *suppurative hydradenitis*, an infection of the sex-linked sweat glands found in the axilla, perineum, and in the inframammary fold of the female breast. Organisms other than the staphylococcus are often present, but skin hygiene with anionic detergents is the initial procedure of choice. Occasionally it may be necessary to excise this entire segment of the skin.

veins may extend into the cavernous sinus. Similar emissary veins are present in the frontal, mastoid, and occipital areas and communicate with the superior longitudinal or lateral venous sinuses within the skull.

The clinical manifestations of septicemia are often so clear as to permit a bedside diagnosis. The important aspects are listed in this order:

1. A *chill* often announces the entrance of particulate foreign protein, in this case the bacteria, into the blood stream. The sensation of cold is pronounced and, in its more severe form, causes muscular contractions so that the patient shivers and the teeth chatter. There is peripheral vasoconstriction so that the extremities become cold and body temperature rises.

2. *Fever* invariably accompanies systemic infection. In the absence of septicemia, it is usually sustained with a mild diurnal variation. In bacteremic infections there are regular and irregular swings of the temperature curve with readings of 40° to 42° C. (104° to 107° F.) as peak values (Chart 1). Such a fever is referred to as *septic* or *spiked*, and marked elevations of temperature are associated with chills. There is evidence that fever up to 40° C. (104° F.) may reflect the accelerated metabolism of the defense reaction and may even be important to it. It is absent, for example, in some of the very severe infections that pursue a fulminant course to the death of the patient. However, fever above 40° C. (104° F.) is, in itself, deleterious and may prove fatal. Because moderate fever may serve a useful purpose, antipyretics and sponge baths are reserved for the comfort of a patient or the treatment of true hyperpyrexia.

3. *Prostration* in septicemia may vary from a feeling of general malaise to complete asthenia. Occasionally the collapse is so complete that there is hypotension or severe shock ("septic shock"). Characteristically, blood transfusion must be supplemented with other measures if the blood pressure is to be restored.

4. *Leukocytosis* is usually present in a range of 13,000 to 20,000 cells per cubic millimeter. The "leukocytosis promoting factor" of Menkin (7) is of such molecular size as to suggest that an observed leukocytosis necessarily implies its intravascular synthesis. Hence, the leukocytosis should suggest the presence of a septic phlebitis. The differential count is often characteristic with a "shift to the left" and disappearance of eosinophils due to the stress effect. In severe infections, there may be a normal or low leukocyte count with such a severe left shift that it is designated as a leukemoid reaction. In agranulocytosis or fulminating infections, the failure of development of a polymorphonuclear leukocytosis is of ominous import.

5. *Blood culture* should be positive at some time in all cases with a diagnosis of septicemia. Repeated cultures with special media are sometimes necessary. Meticulous technic is essential lest a contaminant lead to a false positive with obvious confusion as to diagnosis and effective chemotherapy.

6. The *sensorium* is often disturbed, frequently on the basis of translocation of the extracellular fluid volume with electrolyte imbalance. The patient may be apathetic and listless or he may be apprehensive or delirious. Generalized hyperesthesia of the skin is frequently present. A prominent and frustrating symptom of chronic infection is the loss of morale and desire to get well. This late consequence of infection frequently responds to small doses of testosterone, if the patient is an adult male.

7. *Digestive symptoms* are especially frequent in children, in whom nausea and vomiting may be premonitory symptoms. Anorexia is common to all ages and may require special nutritional care to minimize wasting of body reservoirs.

8. *Metastatic foci* may result from either lymphatic or venous extension. Lymph-node abscesses occur in the channel of drainage. Blood-borne metastases also follow the pattern of proximate infarction with the lung as the primary target of the systemic venous drainage. Early evidence of septic embolism of the lung consists of tachypnea, mild diffuse chest pain, and elevated venous pressure. Productive cough and rales are later developments. Pneumonitis or empyema thoracis are obvious complications of this pattern of metastasis, but lung abscess, pyopneumothorax, and major hemoptysis are also possible. Bacteria may pass through the capillary filter of

neck and back, where carbuncles most frequently occur, resists digestion so effectively that pus never drains adequately.

Before antibacterial drugs were available, carbuncles tended to drain for weeks, often involving more and more tissue and giving a necrotic appearance to the skin. The pain was usually severe, but the systemic manifestations were largely those of fever. The usual treatment was by cruciate incision through the tough derma into the deeper abscess pocket. Less commonly, the lesion was excised with knife or cautery and the wound subsequently skin grafted.

The early use of an effective antibiotic drug has made carbuncle a rarity. The potential destructiveness of these lesions and the increasing drug resistance of staphylococci make it mandatory to test the sensitivity of the infecting organism in every instance. Coexisting diabetes should always be remembered as a possibility.

Suppurative Fasciitis. Although penicillin regularly effects the complete resolution of streptococcal cellulitis, in elderly patients with diabetes and/or arteriosclerosis and cellulitis of the extremity, the lesion frequently fails to subside completely. The important residual is an area of induration and tenderness along a fascial plane. As long as the patient receives penicillin, complaints and systemic manifestations are minimal. However, if the patient is discharged prematurely, there develops an extensive liquefaction of the fascial plane that soon erodes the derma at one or more points to create draining sinuses. This late picture is reminiscent of the hemolytic streptococcus gangrene of prepenicillin days.

It is now established that these areas of residual induration are most appropriately treated by longitudinal incision, evacuation of the mucoid pus, and delayed suture, some three to five days later, under the protective influence of continued penicillin therapy.

SYSTEMIC EFFECTS: SEPTICEMIA

Bacteria may enter the blood stream by way of the lymphatics or the veins. There is good ground for believing that an initial bacteremia of transient and asymptomatic nature may complicate the squeezing of a boil or the extraction of teeth. Such an episode, unrecognized initially, may permit the implantation of bacteria in vulnerable organs or on diseased heart valves to initiate a later septicemia long after the peripheral lesion is healed or forgotten.

Lymphatic extension to the blood stream is nearly always associated with lymphangitis and septic lymphadenitis. The resultant septicemia is characterized by the isolation of invasive bacteria of high virulence in relatively constant numbers per milliliter of blood. The lymphatic pathway is a common route for anthrax organisms, plague bacilli, and, less commonly, hemolytic streptococci. The peripheral lesion is one of cellulitis; the onset is abrupt, and the course fulminant with early peripheral vascular collapse.

Venous extension to the blood stream—as was recognized by John Hunter, Virchow, Welch, and, more recently, Pappenheimer (5)—is the more frequent mechanism of septicemia. Serial blood cultures reveal marked variation in the numbers of bacteria per milliliter of blood. Occasionally there may be actual inflammation of a vein with the characteristic swelling, heat, redness, and tenderness of *septic phlebitis*. Often such an inflamed vein becomes thrombosed, producing *thrombophlebitis*. If a major vein is involved, there is the hazard of fatal pulmonary embolism. More often, detached fragments of the infected thrombus contaminate the blood stream to become implanted elsewhere and initiate secondary, or metastatic, abscesses. The location of the metastatic abscesses frequently identifies the primary focus. The peripheral venous system is suspected when the lungs show septic infarcts of comparable development, but the right side of the heart should be indicted when the lungs show abscesses as well as fresh areas of pneumonitis. Peripheral embolization may result from either left heart endocarditis or suppurative pneumonia. The kidneys, brain, red marrow of bones, lungs, and heart are especially vulnerable to metastatic abscess formation in staphylococcemia (6).

Furuncles or carbuncles of the face and head carry a special hazard of septic phlebitis. An area including the upper lip and the nose is known as the "dangerous triangle" because septic phlebitis of the nasolabial and angular

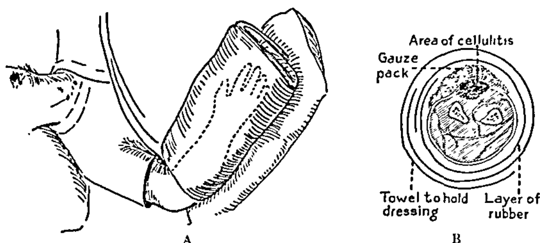


Fig. 7. Elevation and hot wet packs in the treatment of acute cellulitis. A, proper angle of elevation on a pillow; B, diagram of the various layers constituting a wet pack.

tissue, irrigation to remove dirt, foreign bodies, and blood clots, and delayed sutures (Chapter 14). Tetanus prophylaxis with toxoid or antitoxin and streptococcus prophylaxis with systemic penicillin are proper adjunctive therapy.

The treatment of an established infection requires additional measures. These may be discussed under the headings of 1. local measures for cellulitis and suppuration and 2. general measures aimed at the treatment of septicemia.

Local Measures. 1. *Nonoperative Therapy. Rest* not only reduces movement of the affected part and thus minimizes pain, but, more importantly, immobilization reduces the danger of extension of the infection into lymphatics and adjacent tissue spaces. *Elevation* of the part is advisable to promote the local circulation by aiding lymph and venous flow; swelling is also lessened and with it pain. An ordinary muslin sling is the simplest way to put the distal upper extremity at rest. With the patient in bed, elevation of the extremity on a pillow is just as effective. Splints are useful to immobilize fingers or hands and can be applied in addition to the use of the sling. Restriction of ordinary activities may be necessary to insure adequate local rest. Infections of the lower extremities call for confinement to a chair; of the trunk, rest in bed. In no case, of course, should the sling or splint be applied so as to cause pressure sufficient to impair the local circulation. *Relief of pain* is achieved to a considerable degree by rest and immobilization; heat may add to the patient's comfort; cold sometimes does, but has its possible dangers. Drugs such as aspirin, codein, and morphia are to be used freely as indicated during the few hours or days when the pain is most acute. *Local application of heat* aids in the favorable outcome of the inflammatory process whether it is abortion or localization with abscess formation (Fig. 7). It increases the *active hyperemia,* which means a greater blood flow, increased metabolism, and greater leukocytic activity, thereby aiding the reparative forces of the body. The use of heat thus makes the spontaneous response to injury more marked. It also relieves pain in many cases. It must be emphasized, however, that the degree of heat must not be excessive. As ordinarily applied, the effect is quite superficial. Penetration may be increased by diathermy or the infrared ray. The methods of applying heat are described in Chapter 9. Application of cold in acute infections has been recommended by many clinicians and is rather widely used. The authors do not use it. Cold has its definite dangers in the very young, the very old, and over such delicate tissues as the scrotum, eye, and ear.

2. *Operation.* As soon as pus has formed it should be evacuated by incision and drainage, a general principle in the treatment of acute surgical infections. A companion to this rule is the equally important dictum that operations, even simple incisions, should not be done in an area of local cellulitis because

MEDICAL NO.

ST. LOUIS CHILDREN'S HOSPITAL

Name — Admitted July 17 — Ward Surgical

Month	July 27	28	29	30	31	Aug 1	2
Day of Disease	10	11	12	13	14	15	16
Respirations							
Stools	1	Ei	0	Ei	0	Ei	
Total Fluid Intake	2800	2350	2250	2610	2280	2970	3475
Total Urine	1100	550	500	700	—	550	—

DOCTOR'S ORDERS

Chart 1. Septicemia due to hemolytic streptococcus. Note the septic (spiked) temperature curve. The disease started as an apparently innocent infection of the thumb. The patient, a 10-year-old boy, then developed a deep axillary abscess, later an osteomyelitis of the tibia; he died one month later. At autopsy, abscesses and infected infarcts were found in the liver, kidneys, lungs, and so forth. At the present time, chemotherapy would undoubtedly have prevented the fatal outcome, especially if it were used early in the course of the infection.

the lung or new emboli may detach from areas of septic thrombosis in the lung to establish a pattern of peripheral infarction and visceral abscesses. Osteomyelitis of flat bones is a hazard at all ages, but children also show vulnerability of long bones in the diaphysial region. The kidney, brain, joints, and heart valves are other areas of frequent involvement. Unfortunately, many of these cases are difficult to identify and inaccessible to direct surgical treatment.

GENERAL PRINCIPLES OF TREATMENT

The prevention of infection in traumatic wounds is a major objective of initial surgical management. This is accomplished largely by the accepted technics of fasciotomy to relieve tension, débridement to remove devitalized

indicated. Culture at a later stage will be unreliable because secondary skin invaders soon overgrow the original bacteria.

Rest, elevation, immobilization, and heat are continued. In simple, small abscesses, heat may be omitted. Hot soaks may be used intensively for the first 24 hours. The moist dressing prevents drying and thus aids in promoting drainage as well as mechanically loosening debris and necrotic tissue. Prolonged wet heat, however, is unnecessary and often macerates the tissues.

In the extremities, early active motion is important in order to restore function as quickly as possible. It is begun as soon as subsidence of pain permits it and when evidence of healing occurs. *Evidences of healing* are the diminution of such manifestations as pain, local tenderness, swelling, redness, etc. Wrinkling of the skin is a good indication of the subsidence of the inflammatory swelling.

General Measures. 1. *Skilled nursing care.* This is very essential in the care of patients with septicemia. In addition to general hygienic care and psychologic support, there must be a precise record of temperature, pulse rate, respiratory rate, blood pressure, fluid intake and output, and the general condition of the patient. The fluid intake should be sufficient to maintain a good urine volume (about a liter per day) to provide for the elimination of the increased quantity of metabolic end-products occasioned by the fever and the inflammatory process. Both dehydration and edema are to be avoided.

2. *Antibacterial therapy.* Antibiotics should be given systemically on the basis of determined sensitivity using the bacteria cultured from the patient. The sensitivity tests should be repeated at intervals of three to five days as long as viable bacteria are recoverable. Further details of such treatment are discussed in Chapter 5.

3. *Blood and specific plasma fractions.* These agents are also useful on the basis of specific indications. There is evidence that inflammatory fixation of copper retards hemoglobin synthesis, and there is an associated disappearance of reticulocytes as evidence of diminished erythropoesis. Transfusions of whole blood or of washed and resuspended red cells prevent the progression of anemia. Washed red cells are especially useful for the anemic patient with pulmonary complications that make any blood volume increase undesirable.

Staphylococcemic patients often suffer from hypoprothrombinemia in consequence of the destruction of prothrombin by staphylococci. Both whole fresh plasma and vitamin K preparations are useful in its correction.

Gamma globulin is indicated for those patients shown to have agammaglobulinemia with indolent inflammatory response (8).

More recently, interest has been revived in the naturally occurring bactericidal substances of nonimmune plasma. One of these, "properdin," seems especially promising and is under serious investigative study (9).

4. *Steroid therapy* (10). At the present time, cortisone therapy has become established in the management of tuberculosis meningitis, brucellosis, and typhoid fever. It has also been used for its antiphlogistic effect in the treatment of such nonbacterial inflammations as thyroiditis and pancreatitis. It was realized quite early that cortical steroids were similarly effective in the reduction of fever and the elimination of prostration due to pyogenic coccal infection. In general, however, suppression of the inflammatory response results in enhanced invasiveness for both streptococci and staphylococci and cortisone compounds are contraindicated unless there is adrenal insufficiency or peripheral circulatory failure ("septic shock").

Testosterone is occasionally useful to induce steroid euphoria in a depressed patient or to enhance protein anabolism.

PROGNOSIS

The progress, as regards life, is generally excellent for an adequately treated hemolytic streptococcal infection. In a great number of cases, resolution without surgical intervention is the anticipated result. The major exceptions to this general pattern of recovery are the atherosclerotic extremities of the infected extremity.

Although the great majority of staphylococcal infections are localized and respond well to surgical management, evacuation of pus, either spontaneous or surgical, is a rather regular feature of recovery. Staphylococcemia, however, is still a highly lethal disease and frequently terminates in malignant endo-



Fig. 8. Fatal staphylococcal septicemia following an ill-advised incision of a cellulitis of the upper lip. The illustration shows the condition on admission five days after onset of a small "pimple" and two days after it had been incised. At the present time, the use of penicillin would undoubtedly have cured the infection.

they offer a considerable danger of opening tissue spaces and lymphatic and venous channels to further invasion of virulent organisms.

Though incision and drainage is the operation of choice in the treatment of abscesses, occasionally aspiration alone may be effective. In general, however, a well-placed and sufficiently large incision is needed before rapid and complete healing can occur.

The timing of operation is ordinarily not difficult when suppuration is definite. Too early incision, as just discussed, is apt to be dangerous. Delay in drainage prolongs pain, lengthens the period of healing, and aids in absorption and perhaps of extension of the infection. However, in infections of the face above the upper lip, *operation is practically always avoided* in favor of nature's method of spontaneous drainage, especially because of the danger of spreading the infection to the veins leading to the cranial sinuses (Fig. 8). Moreover, in the face, spontaneous drainage is often prompt and effective. The proper timing for operation may be especially difficult when chemotherapy is used, for reasons previously discussed.

The *incision* is best made with a sharp-pointed bistoury knife in simple, superficial abscesses such as furuncles. The point is inserted into the cavity gently and quickly, with the blade directed upward so that by carrying it outward it enlarges the point of entrance without causing any tension on the inflamed tissue. A single, small slit is often sufficient, but in large abscesses it may be lengthened or a second incision made at right angles to it, the so-called cruciate or crossed incision. The opening, in any case, should be large enough to open the cavity adequately and so located as to favor gravity, or dependent, drainage. When multilocular cavities are present, the barriers may be gently broken down, but it should be realized that strands traversing an abscess cavity are usually blood vessels and vigorous rupture of these strands may result in serious bleeding. Rubber tissue drains produce a foreign body reaction and are usually reserved for the drainage of serous cavities. An adequately exteriorized abscess cavity involving soft parts of the extremities requires only that the skin edges be separated by a light pack of five-mesh (preferably nylon) gauze that may be removed in three to five days.

When the skin over the abscess is already necrotic and insensitive, *anesthesia* is often unnecessary, provided no pressure is made upon it during incision. If the overlying skin is inflamed but still too sensitive, it may be quickly frozen with an ethyl chloride spray just before inserting the bistoury knife. If the skin over the abscess is uninvolved by the infection, it may be anesthetized with Novocain. In certain sensitive patients a short gas inhalation may be advisable. General anesthesia is particularly indicated in most infections of the hand and in any large abscess when exploration of the cavity will be necessary. Usually nitrous oxide is sufficient.

The evacuated pus should be smeared and cultured as a routine. Unsuspected organisms, the identification of which may prevent diagnostic and therapeutic errors, may thus be detected. Sensitivity tests against antibiotic agents should be carried out in all serious infections to allow more effective therapy when

7

MISCELLANEOUS INFECTIONS

Tetanus
Gas Gangrene
Erysipelas
Actinomycosis
Venereal Lymphogranuloma
Syphilis
Tuberculosis
Tularemia
Rabies
Vincent's Angina
Noma
Ludwig's Angina
Rat-Bite Fever
Anthrax
Typhoid
Amebic Dysentery
Echinococcus Disease
Granuloma Inguinale
Blastomycosis
Chancroid
Rarer Types of Miscellaneous Surgical Infections

There are numerous miscellaneous surgical infections which cannot be classified readily as regional diseases. They are assembled and discussed in this chapter as miscellaneous infections. The causative agents are extremely varied, including bacteria of various types, viruses, yeastlike organisms, parasites, and agents still undiscovered. Some are very serious, responding poorly to treatment, whereas others respond well to modern chemotherapy. Some of these diseases are not primarily surgical but are caused by injury or animal bites and simulate surgical lesions. Accordingly they are of definite surgical significance not only from the diagnostic standpoint but because some require operative therapy.

TETANUS

The etiologic factor in this disease is *Clostridium tetani*, an anaerobic, spore-forming, gram-negative bacillus which was first described by Nicolaier in 1884. The spores are extremely resistant to drying and will survive boiling for one hour in plain water. It is regularly found in the intestinal tract of the horse, less frequently in many other domestic animals, and to a considerably less extent (20 to 30 per cent) in the intestinal tracts of human beings. The bacillus is likewise widely distributed in soil which has been fertilized with manure.

Since the organism is anaerobic, the disease is more apt to follow deep and punctured wounds in which necrotic tissue and pyogenic organisms are present. The consumption of the oxygen in the tissue of the wound by the pyogenic bacteria creates the anaerobic conditions necessary for the growth of the tetanus organism and thus the production of the disease.

Important in the pathogenesis of tetanus is the fact that, whereas tetanus organisms are harmless if injected in pure culture into the normal tissue of susceptible animals, they multiply and produce toxin if the tissues are damaged by mechanical means or by infection with other bacteria. Although the bacilli have been cultured from lymph nodes adjacent to infected wounds, they tend to remain locally in the wound. In the United States tetanus is more common in the South than in the North, being particularly prevalent in the states bordering the Gulf of Mexico. Confusion still exists as to the mechanism through which the toxin exerts its fatal effect. However, since the work of Abel (1936), it is agreed that the old theory of passage of toxin to the spinal cord by way of the axis cylinders of the peripheral nerves is erroneous. Abel found that tetanus toxin is fixed by the tissues; only when more than a lethal dose was given could any be recovered from the circulating blood and lymph. Moreover, Firor and asso-

carditis (11). It is for this reason that all staphylococcal infections should be given meticulous care during their initial and pre-invasive stages of development.

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symptoms of tetanus. Should this area again be injured, as, for example, by a secondary operation for removal of a foreign body, the patient may then contract the disease. *For this reason, another prophylactic dose of antitoxin must be given at the time such secondary operations are performed, if more than ten days have elapsed since the initial prophylactic dose of antitoxin.* Fortunately, however, if tetanus develops even after the passive immunity produced by the initial prophylactic injection wears off, the disease will be mild. The danger of development of sensitivity to horse serum by subsequent doses of antitoxin is one of the many reasons for starting active immunity with toxid (see below) when the antitoxin is used at the time of injury.

The injection of toxoid,* as popularized by Ramon and associates (2), makes it now possible to produce an active immunity to tetanus lasting four or five years and perhaps permanently. For example, Stafford and associates (3) have found measurable levels of tetanus antitoxin in human serum at least 11 years after active immunization. Active rather than passive immunity is especially valuable in military surgery or for those in whom injuries are extremely frequent because it obviates the need for a second dose of antitoxin which is so apt to result in a serious allergic or anaphylactic reaction. Very little immunity is conferred by the first dose of toxoid. However, when a second dose is given two to four weeks later, definite immunity is conferred within four to six days. A third dose produces a marked rise in antitoxin titer which is maintained for years.

Two injections (1 ml. each) of toxoid are given at intervals of 4 to 6 weeks and a third 6 to 12 months later; a booster dose should be given every 4 to 6 years and at the time of subsequent injury. This method is very effective in prophylaxis and is used for all military personnel. Experiments in mice conducted by Taylor and Novak (4) indicate that penicillin may also be very effective in the prophylaxis of tetanus, but the results were still better when antitoxin was also given. The experiments are of sufficient significance to justify huge doses of penicillin in the treatment of tetanus in human beings.

The question has been raised as to whether active immunization should be started together with antitoxin because of the possibility that antitoxin may interfere with the production of toxoid immunity (5). However, in individuals not previously immunized with toxoid but given antitoxin for treatment of a wound, some authorities (6) recommend that toxoid should be given at the same time but with a separate syringe at a different site. If a patient previously immunized with toxoid sustains an open wound, antitoxin may nevertheless be indicated if 1. the wound is massively contaminated; 2. treatment including the booster dose is delayed more than two or three days; and 3. more than four or five years have elapsed since active immunization.

The great danger in administration of antitoxin is the development of *anaphylactic shock* (manifestations of which include marked tachycardia, laryngeal stridor, bronchial spasm, cyanosis, and collapse), which, if severe, may result fatally within a very few minutes after the injection. Death occurs only in patients extremely sensitive to horse serum and is rare indeed, except as an immediate reaction.

Before tetanus antitoxin is administered, inquiry should be made as to whether the patient has had any injections of serum within the past several years or is subject to asthma, hay fever, or urticaria. If there is any possibility that the patient is sensitive to horse serum, it is preferable to inject a small drop of antitoxin (0.1 ml. of a 1:10 dilution in saline) intradermally with a fine needle. If the patient is sensitive to horse serum, a large wheal surrounded by a hyperemic zone will develop within a few minutes. Under these circumstances, bovine antitoxin may be tried. If the patient is sensitive to that also, desensitization to one (horse serum) should be carried out. This can be accomplished fairly adequately by the frequent injection of graduated doses of serum. The method recommended by Spaeth (7) is as follows: "Inject 0.1 cc. of a 1:100 dilution of antitoxin subcutaneously. Subsequent doses are given at 15 minute intervals. The second to fifth injections are 0.1, 0.2, 0.4, and 0.8 cc. of a

* Toxoid is made by addition of formalin, agar, alum, and other substances to tetanus toxin. The alum-precipitated toxoid appears to be most satisfactory.

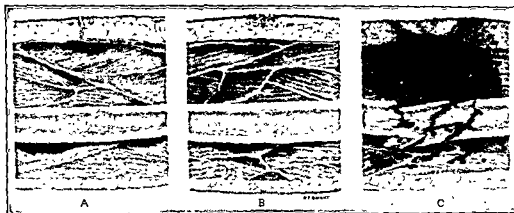


Fig. 1. Types of wounds which are particularly prone to result in tetanus unless adequate prophylactic therapy is instituted (see text). A, punctured wound inflicted by a dirty nail; the anaerobic conditions resulting from this type of wound, along with the foreign bodies (rust, dirt, and so forth), are conducive to the growth of tetanus bacilli. B, wound inflicted by blank cartridge pistol. Note the tiny but numerous perforations of the skin, and the implantation of such foreign bodies as burned powder, paper wadding, and particles of clothing in the subcutaneous tissues. C, wound inflicted by shotgun at close range. Note the enormous destruction of tissue, including bone, and the large number of foreign bodies (shot). This type of wound is also very prone to result in the development of gas gangrene.

ciates (1) found that the toxin does not travel up the spinal cord to the brain; they suggested also that "the toxin in the spinal cord is altered into or liberates a different lethal agent which is transported to and has its lethal effect on vital centers." Their experiments showed that this lethal agent was not neutralized by antitoxin.

Prophylaxis and Immunity. Theoretically every patient sustaining a contaminated wound extending through the skin should have the benefit of prophylactic treatment which may be one of three types: antitoxin, booster dose of toxoid, or procaine penicillin G. However, if careful judgment is exercised, a large percentage of patients with minor lacerations need not be given prophylactic treatment. For example, a superficial laceration sustained by a housewife while washing glassware or dishes which are used and cleaned daily is not apt to be contaminated with tetanus bacilli. Wounds sustained in the street and punctured wounds produced by rusty nails or sharp objects lying in contact with filth or soil are apt to be contaminated with tetanus bacilli. In such instances an injection of 1,500 units of tetanus antitoxin should be given. This dose may be reduced slightly in children, but it *cannot safely be reduced in direct proportion to the weight*. Some advise giving much larger prophylactic doses (Spaeth). It must be emphasized that tetanus antitoxin acts only in neutralizing toxin; it has no effect on the growth of the bacilli. Débridement of the wound (except infected and punctured wounds), removing blood clots and foreign material and excising dead tissue (see Chapter 14), is also important in prevention of tetanus. When the wound is extensive (Fig. 1c) and contamination with tetanus bacilli seems obvious (e.g., gunshot wounds or injuries sustained in barnyards), the prophylactic dose should be increased to 5,000 units. If the patient is seen 24 hours after injury, the initial dosage of 1,500 units should be doubled; it should be doubled for each additional day of delay up to a total dose of 10,000 or 12,000 units. Since the *passive immunity conferred by the administration of antitoxin lasts only 10 to 14 days*, it may also be advisable to repeat the injection in about 10 days, especially if the wound was extensive and tissue destruction so great as to prevent rapid healing. If the wound heals slowly because of infection or other causes, the dose of 1,500 units should be repeated every seven or eight days. Usually, however, the wound has healed so completely by the time the passive immunity has worn off that the local immunity of the tissue surrounding any remaining tetanus bacilli is sufficient to prevent the growth of the organism. It is a well-known fact that tetanus spores may survive in tissues for months without producing



Fig. 2. Opisthotonos in third day of tetanus; death six hours later in convulsions. (From Ashurst. Surgery, Lea & Febiger.)

eign bodies; no attempt should be made to close the wound. If the wound is massive, it should be filled with a creamy suspension of "effective" zinc peroxide and then covered with petrolatum gauze to prevent evaporation. Large doses of penicillin (up to 1,000,000 units per day) should be given on the assumption that the bacilli may still be multiplying in the wound area even though the wound has been excised. Penicillin has no effect on toxin absorption or neutralization. Most authorities advise excision of a healed wound, assuming it is the source of the infection.

The patient must be kept in a quiet and dark room. Every possible effort should be exerted to *control the convulsions with heavy doses of narcotics and sedatives.* Gnagi (8) was among the first to recommend large doses of sedatives (first using sodium amytal) in controlling the convulsions. The rectal administration of avertin has been used a great deal, but its known toxicity on the liver and its tendency to produce hypotension preclude



Fig 3. Risus sardonicus as observed in a patient with tetanus. (Drawn from DeQuervain.)

1:10 dilution subcutaneously. The remaining injections consist of progressively doubled doses of undiluted serum by the intramuscular route, beginning with 0.1 cc." In the presence of active disease, desensitization is conducted more rapidly by giving larger and fewer doses, particularly if convulsions are present. Adrenalin should be given to combat any reaction sustained. Cortisone is also of value.

The term *serum sickness* has been assigned to the late allergic response of the body to the foreign serum and is fortunately encountered in only a small percentage of patients given tetanus antitoxin. This sensitivity may be due to a previous injection of serum or may be an inherited characteristic. In the latter instance, reactions are more apt to be anaphylactic in character. Symptoms appear 4 to 10 days after the injection and are usually ushered in by a generalized itching, urticaria, or erythematous rash of the skin, appearing first at the site of injection. Fever is not uncommon, especially in children; stiffness and pain about the joints is frequently complained of. Generalized enlargement of lymph nodes is common. Such nodes are usually tender to palpation but, of course, do not suppurate. If symptoms are severe, cortisone, ACTH, adrenalin, or one of the antihistaminics like benadryl should be tried.

Clinical Manifestations. The incubation period of tetanus varies from 4 to 10 days but may be delayed several weeks by such mechanisms as insufficient prophylactic antitoxin. In the acute cases death usually occurs within four to five days. The longer a patient lives after the onset of symptoms, the better are his chances of recovery. It is likewise true that the severity of the disease decreases as the length of incubation time increases. On the other hand, the disease is much more serious when the wound is near the brain (i.e., head and neck).

Usually the first symptom noted is limitation of movements of the jaw due to muscle spasm (lockjaw or trismus) although pain in the jaw often occurs early. It should be remembered, however, that lockjaw is most commonly produced by inflammatory lesions about the jaw. Stiffness of the neck and cramps or stiffness of the muscles in the region of the wound soon follow. The muscles of deglutition are also affected, sometimes to the extent that it is impossible for the patient to swallow. Laryngeal spasm may be of sufficient severity to produce respiratory difficulty. Hesitancy in micturition caused by spasm of the sphincter is common. In the more acute cases, spasm of the muscles of the back may be so marked as to produce opisthotonos (Fig. 2). The eyes are usually fixed and staring. Spasm of the facial muscles (Fig. 3) produces the sardonic smile (risus sardonicus) which is notoriously known to accompany the disease. The rigidity of the muscles of the jaw may be so great as to prevent mastication and require liquid feeding, often by means of a nasal catheter. If the catheter provokes laryngeal spasm, it may be necessary to resort to intravenous feeding.

In addition to the tonic spasms described above, clonic spasms or convulsions develop later in the disease. The peripheral irritation producing these convulsions need be nothing more than a slight sound or light touch. The hideous facial expression of the patient in a convulsion is so impressive as not to be forgotten. The temperature may be normal or elevated, except that there is always a terminal hyperpyrexia. Sweating is profuse, particularly in the acute cases. Tachycardia is not pronounced except shortly before death.

Treatment. The treatment of tetanus is curative only when instituted early and in mild cases. As soon as the diagnosis is made, tetanus antitoxin should be administered in large quantities, assuming of course that proper attention is given to the possibility of sensitivity to horse serum as discussed under Prophylaxis and Immunity. Recent investigations suggest that the intravenous method of administration is superior to others. The dose on the day of admission should obviously be larger than on the succeeding days. As a routine, 100,000 to 200,000 units should be given the first day. Additional serum should be given daily in smaller doses as indicated by progress of the disease. Many authorities advise giving 10,000 to 20,000 units of antitoxin intrathecally, although there is really no clinical evidence that this method of administration improves the results.

There is not complete agreement as to the treatment of the wound, but the authors advise early débridement and removal of for-

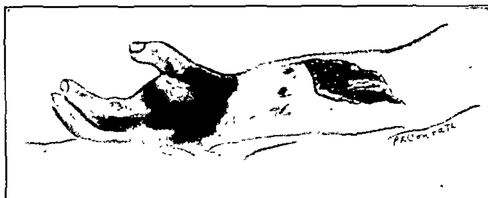


Fig. 4. Gas gangrene in a patient following a compound fracture of the forearm. When admitted to the hospital 30 hours after injury there already were marked swelling of the forearm with crepitation, patches of gangrenous skin, and the typical offensive odor. Amputation was performed in the upper third of the arm several inches above the limits of crepitation. Within 24 hours the crepitation had involved the stump and shoulder. Patient was given massive doses of perfringens (anti-gas gangrene) antitoxin and made a miraculous recovery; sulfonamides and penicillin were not yet available.

10 to 12 hours after injury. The crepitation produced by the forceful diffusion of air into the tissue by trauma may frequently resemble a gas gangrene in its incipiency, but observation over a period of a few hours relative to the progression of the crepitation should quickly differentiate between the two conditions. A profuse, clear or slightly turbid, brownish exudate drains from the wound and is associated with an offensive odor of putrefying flesh, which is so specific as to be almost pathognomonic of the disease. Gas bubbles may be seen in the discharge. Yellowish, bronze-colored, or ecchymotic areas, which rapidly become cyanotic and then gangrenous (Fig. 4), may appear in irregular patches in the skin surrounding the wound due to impaired blood supply. From the onset, the patient appears very ill, presenting many of the symptoms of shock. Delirium is frequently encountered. Pain is variable but usually prominent. The causative organism may be found in the discharge from the wound a few hours after the accident and, usually, before symptoms appear. Occasionally, however, gas-producing, anaerobic bacilli can be found in the wounds (anaerobic cellulitis) of patients who do not develop gas gangrene. Presumably, tissue immunity or efficient treatment has prevented the inception of the disease in such cases.

A roentgenogram of the affected extremity may reveal, in the soft tissues, collections of gas which cannot be demonstrated by palpation. In spite of the brilliant work of Weinberg in isolating various strains of anaerobic organisms capable of producing the disease, it appears that the bacteriology of the disease is still unsettled. For example, the amount of gas produced by the various strains of organisms is extremely variable, and, on many occasions, the disease may be present even in a severe form with the production of only a small amount of gas.

Treatment. Early and thorough débridement (particularly with excision of devitalized muscle) minimizes development of the disease. Badly contaminated wounds in which gas gangrene is apt to develop should be left open after débridement and packed gently with gauze.

Once the disease has developed, active treatment must be begun immediately.

1. *Operation, consisting of exposure of the* involved areas and excision of devitalized tissue, particularly muscle, is perhaps the most important single procedure of value. In advanced cases where toxicity is severe and life seriously jeopardized, immediate amputation of the guillotine type may be indicated; this is rare, however, if proper excision and incision of tissue is carried out.

2. Penicillin in large doses (300,000 to 500,000 units the first day) should be given intravenously and intramuscularly.

3. The wound should be packed gently with a creamy suspension of "effective" zinc peroxide and gauze; the wound is then cov-

its continued use. Sodium evipal and sodium pentothal are satisfactory, particularly for intravenous use in stopping convulsions. Curare may likewise be useful in reducing muscular rigidity if extreme caution is taken regarding dosage. Prevention of convulsions is extremely important because the symptoms produced by the toxin are apparently more responsible for the patient's death than the toxin itself; all clinicians now agree on this point. If muscle spasm prevents swallowing, feeding by nasal tube may be necessary. Usually intravenous feedings are indicated. If laryngospasm is present, tracheotomy will be indicated to aid in the expulsion of pulmonary exudate and to permit easier tracheal aspiration, thus making respiration easier. Cortisone or hydrocortisone may be helpful (9), but these drugs are by no means curative. Good nursing care is very important. As stated, the *prognosis* of the fulminating case is poor. However, if the adequately treated patient survives the first 48 to 72 hours, recovery may be expected. In general, the mortality rate is lower if the disease develops despite a prophylactic dose of antitoxin.

GAS GANGRENE

The causative organism was at first thought to be specifically *Clostridium perfringens (welchii)*, originally designated as *Bacillus aerogenes capsulatus*. It has been demonstrated, however, that there are many other anaerobic organisms capable of producing gas gangrene; in order of frequency they are *Cl. novyi* (*B. oedematiens*), *Cl. septicum* (*Vibrion septique*), and *Cl. histolyticum. Cl. bifermentans* (*Cl. sordelli*) and *Cl. sporogenes* are of less pathogenic significance, the latter organism being proteolytic but producing no toxin. In many instances, colon bacilli and aerobic cocci, particularly the streptococci, prepare the tissues for the development of the disease. Gas gangrene rarely occurs except in massive, dirt-contaminated wounds in which there has been considerable destruction of tissue, especially muscle. A true gas gangrene infection primarily attacks the muscle, which early becomes cyanotic and edematous (*necrotic myositis*). It fails to bleed upon cut section, presumably because of vascular thrombosis or compression due to edema. Invasion may also take place between muscular sheaths or along fascial planes. Compound fractures seem to encourage the development of the disease. Gas gangrene may occasionally be encountered in wounds in which none of the so-called gas bacillus group of organisms is present. In such cases (*anaerobic cellulitis*), very little gas may be noted in the tissues, but discoloration, edema, and destructive features are nevertheless present; the mortality rate is not as high as in the typical gas gangrene.

Clostridial infection really occurs in two forms—a cellulitis and a myositis. The distinction between the two is extremely important, for, while the former is much more common than the latter, it is the infection of the muscle which is the more serious disease and leads to the high mortality. It is probable that much confusion and difference of opinion in regard to treatment in clostridial infections is based upon failure to identify the site of infection. When the superficial tissues are involved, i.e., clostridial cellulitis, treatment may be relatively simple and a favorable outcome expected. However, when the muscle is involved, i.e., clostridial myositis, radical treatment is necessary, and the outcome is frequently fatal. Clinically, cellulitis is distinguished from myositis by the absence of profound toxemia and by relatively moderate pain, whereas in clostridial myositis the onset is sudden, with pain approaching the clinical appearance of shock. The detection of gas in the wound is less important since it may be present with other types of anaerobic infection. Positive differentiation can be made at operation by observing the muscle and the extent of the wound.

Clinical Manifestations. Symptoms are apt to occur 10 to 12 hours after the injury. Fever, tachycardia of an unusual degree, prostration, and restlessness develop early and frequently progress in such a rapid fulminating manner as to cause death in two or three days. A feeling of tension in the wound or of tightness of the dressing is an early and fairly constant symptom; it therefore should never be ignored when complained of by the patient. Swelling about the wound may occur so rapidly as to resemble a progressive hematoma. Crepitation produced by gas in the soft tissues, likewise, may be elicited as early as



Fig. 6. Sulfur granule of actinomyces. Colony of actinomycosis with well-developed clubs at the periphery in a nodule in the peritoneal cavity of a guinea pig inoculated with a culture from another guinea pig. Paraffin section. Low magnification. (From Jordan. General Bacteriology, W. B. Saunders.)

and desquamation appears. Suppuration is uncommon.

Treatment. Despite the low degree of contagion, the patient should be isolated. The mortality rate in the aged and in infancy was extremely high before the institution of chemotherapy. Penicillin is the agent of choice and should be given in a dosage of 600,000 to 800,000 units the first day but may be reduced for the remaining few days during which active treatment will be indicated. With few exceptions, the disease is completely controlled with penicillin in 24 hours.

Erysipeloid is an infection of the skin which resembles erysipelas in appearance only. Often called "fish poisoning," it is acquired from handling fish and is really an occupational disease.

ACTINOMYCOSIS

The etiologic factor in actinomycosis is the actinomyces or "ray" fungus, the most important bacteriologic feature of which is the sulfur granule (Fig. 6) which is just large enough to be recognized by the naked eye and consists of microscopic filaments, coccuslike bodies, and clubs. Finding sulfur bodies in the pus from a lesion establishes the diagnosis, but it should be emphasized that they may be difficult or impossible to demonstrate, especially in sinuses of long duration; in a fresh abscess, however, they are numerous. There are numerous strains of the organism, most of which, as observed in man, are not the same strain that produces lumpy jaw in cattle. Some of the strains grow better culturally under aerobic conditions, whereas others grow better anaerobically. The portal of entry is usually the mouth; the organisms may penetrate the mucous membrane into the neck, enter the lungs by way of the trachea, or be swallowed and attack the cecum and appendix. Actinomycetes which are often found in the mouths of healthy individuals may be the source of the infection. Actinomycosis is a granulomatous disease which tends to invade with destructive characteristics but *does not attack the lymph nodes.* There is scarcely any tissue other than the lymphatic system that is immune to invasion. This no doubt adds to the difficulty in establishing a clinical diagnosis. Bone is readily attacked, and, in one patient observed by the authors, the organism had perforated the base of the skull with the subsequent development of a meningitis. The incubation period is not clearly established but undoubtedly varies within very wide limits.

Clinical Manifestations. The neck is perhaps the most common site affected. The disease is encountered in the abdominal cavity, primarily in the cecum and appendix. It is less commonly observed in the lungs and pleural cavity.

1. In the *head* and *neck,* the infection usually begins as a hard, superficial nodule which finally softens, breaks down, discharges pus and sulfur granules, and ultimately forms a sinus tract (Fig. 7). Before this, however, a boardlike induration surrounding the initial lesion usually develops; the lymph nodes are not involved. Tenderness or pain is not significant but may be pronounced when bone is involved. The sinuses may burrow deeply and form small abscesses or collections of pus, some of which may be secondarily infected if an external sinus is already present. The pus characteristically is thin and heterogeneous

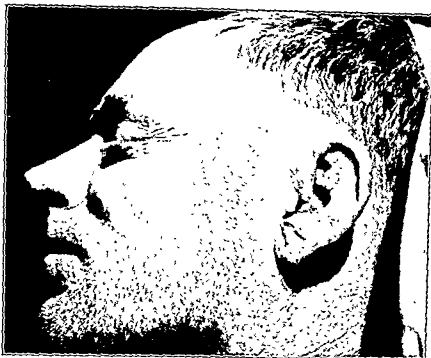


Fig. 5. Erysipelas of the face and ear. Photograph taken 24 hours after onset, which developed with a chill and fever. Note the edema. The raised precipitous edge which is characteristic of erysipelas is present to a moderate degree in this patient. (St. Louis City Hospital.)

ered with petrolatum gauze to prevent evaporation. This dressing must be changed daily.

4. Although there is little evidence that gas gangrene antitoxin is effective, it may be given, providing proper precautions are taken regarding sensitivity as described on pages 103 and 104.

5. Kelly has reported radiotherapy to be effective, but others have not obtained the same favorable response.

The mortality rate should be much below the 50 per cent reported during and after World War I. Langley and Winkelstein (10) reported that the mortality rate among military casualties was only 11.5 per cent in 96 cases in which they utilized surgery, antitoxin, and, particularly, penicillin.

ERYSIPELAS

Erysipelas, which was commonly known years ago as St. Anthony's fire, is an acute inflammation of the skin (Fig. 5), especially of its capillary lymphatics, and is caused by *Streptococcus erysipelatis*. At present, it is fairly rare and not very serious because it is so effectively amenable to chemotherapy. Usually there is no visible lesion to explain the entrance of the organism into the skin. Presumably the invasion is made through tiny fissures or lesions microscopic in size. The contagious element to the disease has been exaggerated. Cooke (11) is of the opinion that the disease is contracted by autoinoculation, that is, without coming in contact with an active case of erysipelas. The fact that the incidence of the disease shows equal distribution in males and females during infancy and childhood but changes to 60 and 40 per cent respectively after the age of puberty, when shaving is prevalent, appears to support the theory of autoinoculation.

The skin of the face is by far the site most commonly affected, but the skin of any portion of the body may be attacked. A red, edematous, tender, and slightly raised area appears quite suddenly and usually shows a tendency to spread rapidly but in no specific direction. Almost simultaneously with the appearance of the initial lesion, the patient develops fever and frequently chills. Fever, however, may on rare occasions be absent. Pain and tenderness are extremely variable and may be absent. The border of the lesion is sharply defined and presents the most conspicuous evidence of inflammation. The reaction at the point of origin gradually fades,



Fig. 9. Multiple sinuses of the back due to actinomycosis, in a girl 16 years of age. Onset two years previously with pain in chest, followed two weeks later by the development of a sinus under the right breast. Since that time, numerous other sinuses appeared, particularly over the back. X-ray revealed a destructive process involving the first and second lumbar vertebrae and a thickening of lung markings; each process resembled tuberculosis but was undoubtedly due to actinomycosis. Sulfur granules were found in a fresh abscess on the back but were absent in the discharge from the chronic sinuses.

able there is no way of determining whether or not the actinomycetes were instrumental in the development of appendicitis in such instances; however, it appears that the disease is often primary in the appendix and spreads to the cecum from that point. Usually, the onset is insidious with mild pain in the right lower quadrant associated with the development of a mass in the cecal region. Sinuses may form anywhere about the abdomen and are frequently observed about the pelvis and back (Fig. 9). The liver may become involved but usually only as a manifestation of a generalized infection; subphrenic abscesses are occasionally encountered arising from lesions in the liver or cecum.

3. *Thoracic* actinomycosis usually follows invasion of an active initial lesion in the neck or abdomen. Aspiration of the organisms into the respiratory passages may also be responsible for the disease. The symptoms may simulate those of pulmonary suppuration (particularly tuberculosis), including cough, pain on respiration, fever, expectoration, sweating, and loss of weight. As the disease progresses, the pleura and finally the thoracic wall, including the ribs, are involved with the subsequent development of sinuses leading to the exterior.

Treatment. Contrary to general belief, a cure may be expected if the diagnosis is made early. Perhaps the most important of the various therapeutic measures is surgical, i.e., adequate drainage of abscesses, excision of necrotic tissue, and free drainage of the wound (Wangensteen). Penicillin is quite effective, but it must be given in huge doses (as much as 1,000,000 units per day) and continued over a long period. Sulfadiazine, in a dose of about 4 gm. per day for an adult, should be given simultaneously. On certain occasions, x-ray therapy is helpful. It is to be emphasized, however, that, when the disease is disseminated so that major organs, such as the liver and bones, are involved, the chance of obtaining a cure is greatly diminished, regardless of the type of therapy used.

VENEREAL LYMPHOGRANULOMA

This disease is known by several names, including lymphogranuloma inguinale, esthiomene, tropical bubo, and lymphopathia venereum. The French investigators (Durand, Nicolas, and Favre), who described it in 1913 as a definite entity, recognized it as being of venereal origin and as being caused presumably by a virus which entered the body through a tiny unnoticed primary lesion on the genitals. The incubation time varies between five days and three weeks. The Negro race is affected much more commonly than the white. Manifestations are encountered much more commonly in females than in males.

Before the advent of penicillin and other agents so effective in the treatment of syphilis, Gray and associates (12) found the disease slightly more prevalent in the Negro race than was syphilis. They noted that, in a series of nearly 500 Negro hospital patients, 40 per

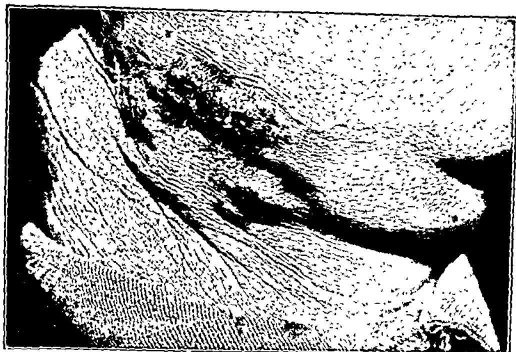


Fig. 7. Actinomycosis of jaw. (From Wohl. M.A. J.A.M.A.)

and contains flaky necrotic material. Sulfur granules are rarely demonstrable except in fresh abscesses. Fever may or may not be present.

2. The *abdominal* type presumably is caused by implantation of swallowed organisms upon a small lesion or ulcer in the mucosa of the intestine, usually the cecum or appendix (Fig. 8). The first symptoms of cecal actinomycosis may be acute and *may simulate appendicitis.* Thus, many cases of actinomycosis of the cecum develop after the patient has been operated on for acute perforated appendicitis. With the evidence avail-

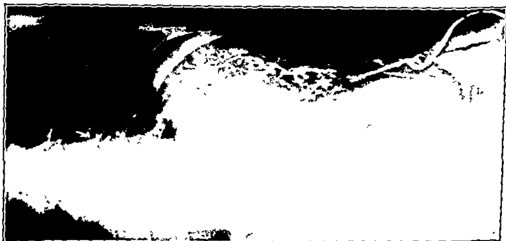


Fig. 8. Abdominal and thoracic actinomycosis. The patient, a 65-year-old housewife, first developed acute abdominal manifestations, was operated upon, and a perforated appendix removed. A mass appeared in the right lower quadrant three months later, which was incised; pus was encountered in which the ray fungus was found. Later, abscesses formed in the lumbar region and thoracic cavity from which the actinomyces were identified and cultured. The x-ray photograph was taken after Lipiodol had been injected into the sinus in the abdominal wall leading to the abscess; note the outline of the bronchi and the shadow indicating the subphrenic and pleural abscess. This patient was observed before the advent of chemotherapy. Treatment consisted of intensive radiotherapy, sodium iodide, and incision and drainage of abscesses. All incisions remained healed for 15 years, during which time the patient was observed.

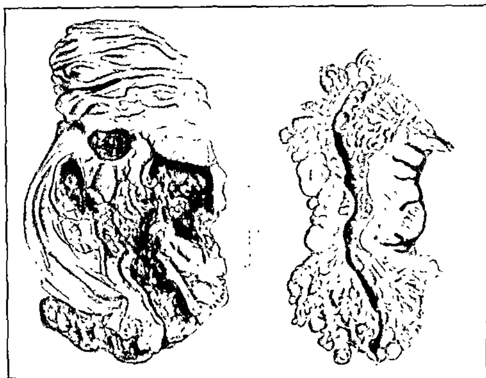


Fig. 11. Longitudinal section of stricture of rectum due to venereal lymphogranuloma. Each illustration represents specimen removed at operation. Note that the stricture extends not more than 6 to 8 cm. above the sphincter. Areas of ulceration are found scattered over the scarred mucosa. (Drawn from Gatellier and Weiss.)

prominent and the nodes may suppurate. If the suppurating nodes are not incised, they readily break through the skin spontaneously and form sinuses. Suppuration and sinus formation may last for variable lengths of time. In some instances, healing has taken place in as short a time as three weeks. On other occasions, the nodes have been known to exist for as long as two years.

In the female, ulcerating proctitis with mild tenesmus and passage of blood, mucus, and pus in the stool is usually the first significant symptom. This may persist for two or three years or longer. At least three-fourths, and perhaps all, of the benign strictures of the rectum are caused by venereal lymphogranuloma (Fig. 11) and are a sequel (two to three years later) to ulcerative proctitis. Benign stricture of the rectum will produce symptoms referable to the narrowing of the lumen —namely, tenesmus and diarrhea with liquid or pencil stools. These benign strictures of the rectum persist indefinitely, but the patients frequently adjust themselves so that they have frequent liquid stools and suffer very little inconvenience from the stricture. Occasionally condylomatous lesions about the anus are observed (Fig. 12). Elephantiasis of the genitals (particularly the vulva and penis) is not uncommon. Fistulas about the rectum are common.

Diagnosis. The Frei test is remarkably valuable and accurate, since positive tests have been obtained as long as 12 to 15 years after the onset of the disease. The antigen is injected intradermally in the quantity of 0.1 ml. A typical positive reaction appears in the skin surrounding the induration.

When the disease primarily affects the lymph nodes, it is often confused with lymphadenitis caused by a chancroid. The gradual enlargement of the lymph nodes, associated with a variable amount of pain, followed ultimately by suppuration, are identical in the two diseases. However, an important difference is the size of the initial lesion, which, in lymphogranuloma, is small (seldom larger than 0.25 cm. in diameter), and, in a chancroid, is large (1 to 2 cm. in diameter). The initial lesion in a chancroid is apt to be mul-

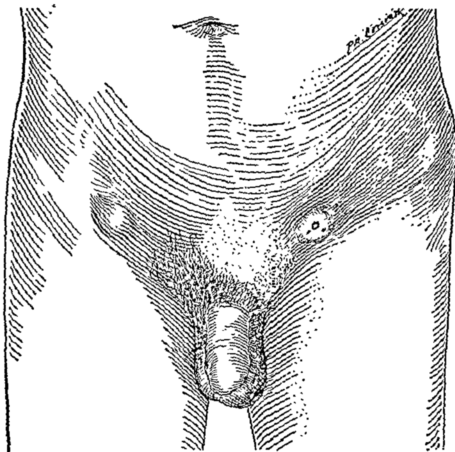


Fig. 10. Bilateral lymphogranuloma inguinale. The nodes on the patient's left have suppurated, resulting in the formation of a sinus as noted. The nodes on the right are enlarged but did not suppurate, although about five months were required for subsidence of the process on each side.

cent of the males and 40 per cent of the females had positive Frei tests. In a smaller series of white patients, they obtained positive Frei tests in only 3.4 per cent, again with an equal incidence in males and females. Only a small portion of the patients with positive Frei tests had symptoms of the disease. Since this test is known to be highly specific, it may be assumed that the vast majority of patients with positive Frei tests had recovered from the disease without clinical manifestations. The pathogenesis, along with other data on the transmission of the disease described by various authorities, has been discussed in detail in the monograph by Stannus (13). The disease is readily produced in various types of animals by local inoculation, particularly into the brain.

Clinical Manifestations. The disease manifests itself in one of three ways. In men the most common feature is 1. involvement of the inguinal lymph nodes which frequently goes on to suppuration. In women the most common complaint is referable to 2. an ulcerative proctitis which, at least in Negroes, frequently results in 3. stricture of the rectum. Occasionally inguinal lymphadenitis and ulcerative proctitis exist simultaneously.

The onset of the disease is frequently characterized by diffuse severe abdominal pain of a cramping nature. Fever, nausea, and, rarely, vomiting may accompany the abdominal pain. Loss of weight is commonly observed and multiple arthritis is not uncommon. Severe systemic manifestations, however, are usually associated with extensive infection and fistulas around the rectum and perineum; they occur almost always in the female and often two or three years following the onset of the disease.

In the male, the lymph nodes of one or both sides enlarge insidiously without the production of much pain (Fig. 10). After a few weeks the pain and disability become more



Fig. 13. Chancre of the penis.

frequent dilatations, but, in severe cases, especially those with superimposed infection and multiple fistulas, colostomy may be indicated.

SYPHILIS

Syphilis is caused by *Treponema pallidum* (*Spirochaeta pallida*) and is acquired primarily by sexual contact. Because penicillin is so effective in therapy, this disease has become much less frequent during the past 10 years. Syphilis may affect any organ of the body and in such a variety of ways that the disease is of surgical significance, especially from the standpoint of diagnosis. Numerous serologic tests, including the Kahn, Wassermann, Kline, Kolmer, and Hinton, are in use and are extremely valuable in establishing the diagnosis.

The *primary* stage, or chancre, appears usually on the genitals (Fig. 13) and sometimes on the lip, three to four weeks following exposure. The lesion is flat, indurated, buttonlike, and ulcerates after several days. From this ulceration, the spirochete is readily isolated and identified with the aid of dark field examination. The lesion is indolent and does not heal for several weeks without active treatment. Regional lymph nodes may enlarge painlessly but never break down unless secondarily infected with pyogenic organisms. Six to ten weeks after the primary lesion appears, the *secondary stage*, which is an expression of the systemic invasion by the spirochetes, appears. The accompanying eruption over the skin and mucous membranes (mucous patches or leukoplakia) has varied characteristics. At varying intervals, from a few months to several years, the *tertiary stage* develops. The gumma which typifies this stage is of variable size and may appear in any tissue or system of the body. Gummas are smooth and soft, and, because of associated arterial lesions such as thrombosis and endarteritis, are avascular and may break down, forming a necrotic mass. (Fig. 14). True suppuration, however, does not occur without secondary pyogenic infection. Cutaneous tertiary lesions or syphilides may appear and produce stubborn ulcerations, which are commonly seen on the leg.

Mouth. Hutchinsonian teeth and scarring about the mouth are manifestations of congenital syphilis. Primary lesions may occur on the lips or tongue and be occasionally mistaken for carcinoma, but gummas of the tongue are of much greater surgical significance because of the enormous amount of destruction of tissue in some cases and because of the frequent association with carcinoma. The differentiation between gumma and carcinoma of the tongue frequently cannot be made without a biopsy. Occasionally syphilitic leukoplakia simulates that associated with squamous cell carcinoma (see page 385).

Nose and Throat. Although redness and edema of the pharynx are rather constant accompaniments of early syphilis, the rarer lesions (gummas) are much more significant surgically. Gummas of the nasal septum may

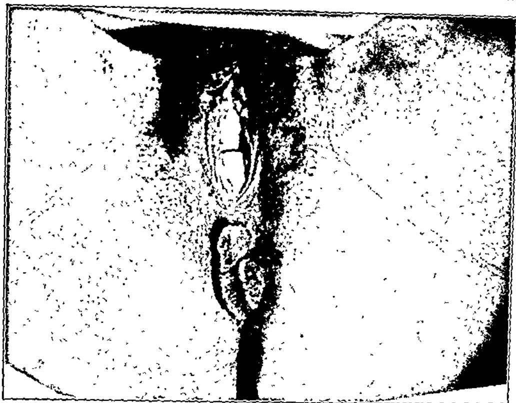


Fig. 12. Condylomas due to venereal lymphogranuloma. Such lesions develop insidiously and may or may not be associated with ulceration. This patient had a rectal stricture; the Kahn test was negative. Previous to identification of the disease in 1913, almost all lesions of this type, as well as strictures of the rectum, were considered to be of syphilitic origin; most of them are due to venereal lymphogranuloma.

tiple; in lymphogranuloma it is usually single and even unnoticed in males but is frequently multiple in women. Sensitivity tests will usually differentiate—the Frei test is specific for venereal lymphogranuloma and the Dmelcos test for chancroid.

When limited to the inguinal lymph nodes, the disease may rarely simulate tuberculosis clinically, but it should be remembered that tuberculosis of the inguinal lymph nodes is extremely uncommon; microscopic section of the lymph nodes closely resembles tuberculosis. Giant cells are frequently observed in venereal lymphogranuloma. However, one feature is apparently reasonably diagnostic; viz., a lymph node, removed in the proper stage of suppuration, will reveal microscopically tiny areas of caseation surrounded by a palisading of epithelioid cells. Such miliary abscesses may be round but are usually star-shaped. Pus obtained by aspiration from these suppurating nodes reveals no growth on culture and will, of course, not produce tuberculosis when injected into a guinea pig.

The disease may be confused with granuloma inguinale, in reality, only because of similarity in the terms. Granuloma inguinale is likewise a venereal disease, but it is manifested by ulcerations about the perineum which are rather superficial and do not attack the lymph nodes. Such ulcers may be located on the genitals or in the groin.

Treatment. Of the antibiotics, aureomycin (30 to 40 mg. per kg. per day) and chloromycetin (60 mg. per kg. per day) are the most effective. Penicillin is only slightly effective. Streptomycin is of no value (Long and associates) (14). None of these agents will be of value in treatment of strictures except for secondary perirectal infection. The infection of the inguinal lymph nodes is treated as a low grade inflammatory lesion. When suppuration appears, incision is recommended. On a few occasions mere aspiration of pus from the inguinal abscess has been sufficient to relieve symptoms and prevent further suppuration. Drainage of abscesses relieves the acute inflammatory manifestations but is by no means curative. Obstructive symptoms due to the stricture may often be combated with

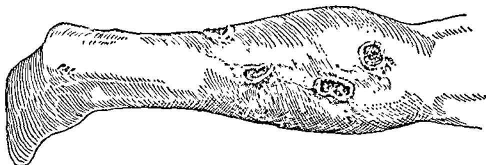


Fig. 15. Syphilitic ulcers (tertiary lesions). Note the punched-out appearance. Such ulcers are usually multiple and the discharge rather profuse.

problems that are encountered in gumma of the brain which, though rare, may present all the symptoms and signs of a brain tumor. Occasionally, visceral crises (in tabes), consisting of severe abdominal pain, simulate an acute intraabdominal surgical condition. In addition, however, to the presence of tabetic signs, a careful consideration will usually reveal a lack of muscle spasm, tenderness, leukocytosis, nausea, and vomiting, which would be present in an acute surgical process. Paretics are occasionally seen in the emergency room because of prostration and coma.

The tabetic bladder may result in a variable amount of incontinence and urinary retention, but infection is rarely significant unless induced by catheterization.

Treatment. The treatment of syphilis is not a surgical problem, but it should be emphasized that the superiority of penicillin over arsenic compounds has completely revolutionized therapy. Salvarsan now has only historic interest. Penicillin given in large doses for 10 or 20 days will cure over 90 per cent of cases, although involvement of the cardiovascular and cerebral nervous systems requires the care of a specialist because the residual damage is so severe that complicated therapy for a prolonged period is often necessary. Chloromycetin is also very effective in syphilis.

TUBERCULOSIS

The causative agent of human tuberculosis, *Mycobacterium tuberculosis*, was discovered by Koch in 1882. Two strains of *M. tubercu-*

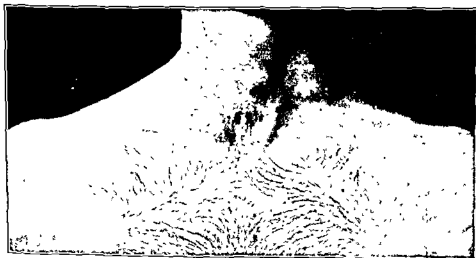


Fig. 16. Gumma of the right sternoclavicular joint in a young man, aged 28. Within a few weeks after the onset of intensive antiluetic therapy the swelling disappeared completely. (Washington University Clinic.)



Fig. 14. Gumma of forearm. Date of primary lesion unknown. The patient, a 45-year-old female, complained of a mass in the forearm which, under intensive treatment, rapidly softened and sloughed, leaving a deep ulcer as shown in the photograph. Healing was complete in a few weeks.

produce a perforation with a subsequent depression of the nasal bridge. Such deformities can only be corrected by plastic operations such as cartilage transplantation.

Gastrointestinal Tract. Syphilis of the stomach may produce clinical signs and radiologic findings similar to carcinoma of the stomach. The question of syphilis of the stomach always arises when manifestations of gastric ulcer or carcinoma occur in a patient with a positive Wassermann. Surgical excision of the ulcerated area is usually indicated because the cicatricial obstruction which follows chemotherapeutic healing will probably make operation necessary anyway. For that reason differential diagnosis is somewhat academic, except that differentiation from carcinoma is helpful or even necessary to aid in determination of the extent of resection.

Many years ago huge gummas of the liver were commonly seen and presented considerable difficulty in differentiation from intra-abdominal cysts and benign tumors which might justify operation. Due to modern chemotherapy, such lesions are rare. An acute syphilitic infiltration of the liver of the cirrhotic type, with the production of jaundice and other signs of portal obstruction, is more common.

Gummas were formerly thought to occur frequently in the terminal portion of the rectum and, after the diffuse scarring which follows the massive destruction of tissue, to terminate in a stricture. However, practically all strictures of the rectum are caused by lymphogranuloma inguinale (see page 112).

Skin. Reference has already been made to the primary and secondary lesions of the skin. More significant surgically are tertiary lesions (gummas) which appear in the subcutaneous tissues as indurated nodules, breaking down through the skin, forming ulcers. Such ulcers are usually punched out, occurring most commonly on the upper part of the leg, but they may be encountered any place on the body (Fig. 15).

Bones and Joints. Infection of bones, especially the long bones, is common and manifests itself in one of three ways: 1. periosteal form; 2. hyperplastic or associated with overgrowth; and 3. destructive. Joints may become involved (Fig. 16) to such an extent that disability is pronounced (Charcot's joint). These features are discussed in detail in Chapter 24.

Central Nervous System. The most common types of syphilitic invasion of the central nervous system are tabes and paresis, but these conditions do not present the surgical



Fig. 17. Suppurating tuberculous lymphadenitis of the femoral and inguinal nodes. Tuberculous lymphadenitis in this location is infrequent; the cervical and mediastinal nodes are involved most commonly. The patient is a Negro boy aged 11, who noted a fluctuant swelling in the femoral region. Six months previously, incision by a family physician resulted in the evacuation of an ounce or two of pus. The ulceration noted in the illustration developed since the incision. Total excision of the involved lymph nodes was carried out; complete healing occurred after two or three weeks. No other focus of tuberculosis was found at any time. Below the photo is a photomicrograph of the excised tissue, showing tubercle formation; note also the marked necrosis.

tubercles. On other occasions, ascites is more or less pronounced, and the intestines may be matted together with adhesions which may likewise surround caseous areas. Not infrequently, the disease may be much more acute and ushered in with symptoms suggestive of a subacute appendicitis. Treatment is really nonspecific, yet, for some unexplainable reason, definite improvement nearly always follows celiotomy even though a biopsy for microscopic diagnosis is all that is done.

Tuberculosis of the Bones and Joints. As previously stated, the bovine bacillus is probably responsible for invasion of the bone and usually attacks children or young adults rather than adults. Vertebrae are most frequently affected although the head of the femur is also commonly diseased. The most important feature in the treatment of tuberculosis of the bone or joint is rest and immobilization. A more detailed description of tuberculosis of bones and joints may be found in Chapter 24.

Genitourinary Tuberculosis. The most important organ of this system attacked by tuberculosis is the kidney. Destructive abscesses appear but frequently with no significant symptoms until the disease is implanted in the bladder, at which time frequency and urgency of urination appear. Red blood cells and pus cells, as well as tubercle bacilli, are found in the urine. Vague pains in the loin,

losis, the human strain and the bovine strain, can produce the disease in human beings; these were differentiated by Theobald Smith. The organism gains access to the human body by inhalation or by ingestion into the stomach. Considerable evidence has accumulated to suggest that most primary infections of the lymph nodes, which were known years ago as scrofula, are caused by the bovine strain. The same may be said about tuberculosis osteomyelitis of the long bones and hyperplastic tuberculosis of the cecum. These are commonly seen in the British Isles where pasteurization of milk is not widespread, but they are rarely encountered in the United States where pasteurization is general. It is assumed that the bovine bacillus, in contaminated milk, may penetrate the pharyngeal mucosa or tonsil, thereby infecting the cervical lymph nodes, and, by ingestion, give rise to certain types of alimentary tuberculosis. The fact that tuberculosis of the cervical nodes is decreasing as the practice of pasteurization of milk becomes more prevalent lends support to this theory.

The use of Kochs' Old Tuberculosis (OT) or of purified protein derivative (PPD-Siebert, 1934) may be helpful in diagnosis. A negative tuberculin test excludes active infection except occasionally in overwhelming infection or in the early stages (first two or three weeks) of the infection.

Tuberculosis is a large worldwide problem. The prophylactic efficacy of BCG vaccine (Calmette, Guérin, and associates, 1925) is still uncertain, although vaccines of slightly modified types are still being used with the hope that the disease may be thereby prevented. During the past several years, the death rate has decreased sharply because of the new agents used in therapy, but the incidence has decreased only slightly.

Pulmonary Tuberculosis. Surgical procedures may be extremely efficient in arresting the disease and encouraging healing. Phrenicectomy (avulsion of the phrenic nerve) paralyzes the diaphragm on the side of the operation and obtains rest for the affected lung; this rest is, of course, impossible if respiratory movements are normal. Perhaps a more efficient method of obtaining rest and immobilization of the lung is extrapleural thoracoplasty. Frequently, if the disease is confined to the apex, removal of the ribs over the apex (apical thoracoplasty) is sufficient to obtain the desired mechanical compression. For further discussion of the surgical therapy of pulmonary tuberculosis see Chapter 36.

Tuberculosis of the Lymph Nodes. As stated, involvement of the lymph nodes is uncommon in the United States, except in the chronic, calcified, asymptomatic form. Onset is usually insidious without constitutional symptoms. Cervical and mediastinal nodes are most commonly affected. The nodes in the axillary and inguinal region (Fig. 17) and in the intestinal mesentery are less commonly involved. For detailed description of tuberculosis of the lymph nodes see Chapter 26.

Intestinal Tuberculosis. Ulceration of the cecum (Fig. 18) may be produced by the tubercle bacillus and may clinically resemble carcinoma or idiopathic ulcerative colitis. However, roentgen examination with barium is of diagnostic aid if the lesion is in the sigmoid because tuberculosis rarely affects this part of the colon. The first symptoms of tuberculosis of the cecum are apt to be inconstant cramping pain in the abdomen associated with diarrhea of varying degree and possibly nausea and vomiting. If the ulceration is present throughout the entire colon, the symptoms may vary but little from those produced by a localized tuberculosis. In either case blood should be found in the stool. Intestinal tuberculosis is apt to be associated with, or secondary to, pulmonary tuberculosis, thereby adding considerably to its seriousness.

Occasionally, tuberculosis is demonstrable in microscopic sections of excised fistulous tracts resulting from ischiorectal abscess and may be the primary etiologic factor in the production of the abscess. In such instances there is usually an associated generalized tuberculous infection; it should be emphasized, however, that tuberculosis is found in a very small portion of the fistulas about the rectum and anus.

Tuberculous Peritonitis. Invasion of the peritoneal cavity is, of course, a secondary infection, primary perhaps to tuberculosis of the mesenteric lymph nodes, intestine, or Fallopian tube. The symptoms are extremely variable, and diagnosis is frequently made only at abdominal exploration. The intestines and omentum are commonly studded with

There are innumerable other regions where tuberculosis may develop, but most of them are so rare as not to be of great importance. Tuberculosis of the *larynx* is a slowly developing, painful disease, responding poorly to therapy. Invasion of the *skin* with the production of ulcers was common years ago but is rarely encountered now as a primary lesion. Tuberculosis of the *breast* occurs rarely; it is discussed in Chapter 35.

Treatment. The discovery of streptomycin by Waksman and Schatz in 1944 introduced a new era in the treatment of tuberculosis. Since then numerous other drugs including dihydrostreptomycin, neomycin, and viomycin have been employed. Unfortunately, the organisms tend to develop a resistance to these agents after several weeks of treatment. However, para-aminosalicylic acid (PAS) and isoniacid seem to decrease the degree of this resistance. For this reason, 1 gm. streptomycin twice weekly and 12 gm. PAS (in terms of free acid) daily is a common method of therapy. If sensitivity develops toward PAS, 0.15 to 0.3 gm. isoniacid may be given daily instead. Treatment should be carried out for 10 to 15 months. As stated, therapy with the drugs mentioned above has resulted in a much lower mortality rate but, as yet, has not greatly decreased the incidence of the disease.

TULAREMIA

This disease was first recognized by McCoy in 1911 as a plaguelike epidemic occurring in ground squirrels. A year later McCoy and Chapin isolated a bacillus which they called *Bacterium tularense* after Tulare County, California, where the epidemic was investigated. The reports of a few cases in human beings appeared at sporadic intervals, but it was not until several years later that the disease was described in detail and the name tularemia given it by Francis.

The disease is apparently prevalent in almost all the wild life of this country, especially in the rabbit, squirrel, ground squirrel, woodchuck, fox, and coyote. In animals, transmission is by a parasite, such as the tick, or by contamination of mouth lesions in carnivorous animals. The tick is the most common vector in army recruits; in civilians nearly 95 per cent of the infections are contracted directly from rabbits and nearly always while handling or dressing them. In most instances, a history of sustaining a minor injury of the hands during the process of cleaning the animal can be obtained from the patient. The occurrence of the infection in laboratory workers suggests that the organism may invade the unbroken skin and produce the disease. The disease is not contracted by eating infected rabbits, providing the meat has been thoroughly cooked. The incubation time varies in extremely wide limits but averages about six days. Natural immunity in human beings is apparently not common, as is corroborated by the fact that numerous laboratory workers coming in contact with the bacterium (now called *Pasteurella tularensis*) have contracted the disease. It seems probable that tularemia is destined to become more frequent, but fortunately the mortality is comparatively low, approximately 4 per cent.

Clinical Manifestations. The disease manifests itself clinically in six different clinical forms. 1. The *ulceroglandular* type is by far the one most frequently recognized. The onset is abrupt with the typical features of an acute systemic infection including fever, chills, prostration, anorexia, headache, backache, and occasionally delirium. The injury (usually on the hand), through which the disease was contracted, shows little tendency to heal and, by the time clinical symptoms appear, begins to ulcerate (Fig. 19). If the portal of entry is microscopic, a large, indurated, only slightly tender papule appears at this time. As the disease progresses the central portion becomes necrotic, and a superficial sinus or ulcer develops. Soon after the initial lesion reveals these signs of activation, the lymph nodes draining that area become enlarged. These nodes, situated in the epitrochlear and axillary regions, are discrete and even during the process of suppuration cause little tenderness or pain. Suppuration of one or more of these nodes usually occurs at one time or another during the course of the disease. The period of febrile reaction is short, except in the serious and fatal cases, but returns intermittently after intervals of several days. Symptoms of this type may be encountered 10 or 12 weeks after the onset of



Fig. 18. X-ray of patient (Negro man, aged 35) after injection of a fistulous tract in the right lower quadrant with Lipiodol, most of which has passed into the cecum.

mild fever, and malaise are common symptoms as the disease progresses. If the disease is unilateral, as may be determined by pyelograms, nephrectomy is indicated. Elimination of the focus of infection practically always eradicates the infection in the bladder (see also Chapter 40).

In women, the Fallopian tubes occasionally are infected. First, tubercles appear, but soon the fimbriated ends of the Fallopian tube become sealed off and the walls become thickened; caseous, thick pus is present in varying quantities. In the male, tuberculosis occasionally invades the epididymis, producing a mildly tender and painful organ which increases moderately in size and ultimately may break down and form a sinus extending through the scrotal wall. Removal of the epididymis yields satisfactory results. Occasionally the prostate and seminal vesicles are invaded.

Tuberculosis of the Central Nervous System. Invasion of the nervous system may manifest itself either as a meningitis, which, although of many weeks duration, is universally fatal, or as a tuberculoma. The latter lesion may produce symptoms identical to those encountered in brain tumor.

pulsive desire to run about aimlessly. He may become unusually affectionate but, with strangers, is apt to be irritable. Within a day or two he shows a desire to leave home, and it is during this period of two or three days, before paralyses set in, that he inflicts so much damage. The first group of muscles to become paralyzed are those controlling the lower jaw, which then drops and reveals profuse salivation. Paralysis of the hind quarters is usually followed in 24 or 36 hours by death. The saliva of the animal is infective four to six days before symptoms develop. The diagnosis in the animal is confirmed by demonstration of Negri bodies in the brain; these bodies are less readily found if the animal is killed before significant symptoms develop. Due supposedly to a natural immunity, only 20 to 30 per cent of people bitten by rabid dogs will contract rabies if untreated. However, since the mortality rate of the disease is so high, this offers no excuse for failure to give the Pasteur treatment if there is the slightest chance the animal was rabid.

Prevention. Injection of attenuated virus (Pasteur treatment) is by far the most effective prophylactic therapy. If there is the slightest possibility that the animal was rabid, the patient should be given this specific therapy. As first devised by Pasteur, it consisted of the injection of an emulsion made from a diseased spinal cord which was attenuated by drying for 14 or 15 days. Delay does not interfere with efficiency of the treatment until more than 12 to 14 days have elapsed since the patient was bitten. Opinions differ as to how the wound should be treated, but Shaughnessy and Zichis (16) have shown experimentally that washing the wound with soap and water is more effective in prophylaxis than using any cauterizing chemicals. In any case the wound should not be closed but should be left open.

Clinical Manifestations. The incubation period is variable, averaging 50 or 60 days, but may be as short as 10 days or as long as two years. Because of the fact that the virus apparently attacks chiefly nerve tissue and evidently makes its way to the spinal cord and brain through nerves, the *incubation time is shorter when the bite is inflicted on the face or trunk.* In man the disease is ushered in by an ungovernable restlessness and increased irritability and sensitivity to mild stimuli. He may suffer wild hallucinations and usually becomes maniacal soon after onset. Convulsions may be produced by the slightest stimulus, especially by draughts of air. As the disease progresses, hydrophobia is noted. This term is quite suitable because of the fact that, when the patient attempts to drink water, he is seized with such severe pain and laryngeal spasm that respiration may be impossible; the mere sight of water may bring on these attacks of suffocation and pain. After two to four days generalized paralysis develops; death follows inevitably and rapidly.

Treatment. Prophylactic therapy is effective as described above. After the development of the disease there is no known method of treatment which offers any hope of recovery. Symptoms are treated as they arise merely with the idea of making the patient comfortable. Convulsions and spasm should be controlled, if possible, by sedatives.

VINCENT'S ANGINA

Vincent's angina (trench mouth) is an acute inflammatory disease of the mouth, gums, or pharynx which is caused by a mixed infection of Vincent's fusiform bacilli and spirochetes. The lesion is really a form of stomatitis, may be multiple, and usually starts as a red edematous area in the center of which a small patch or ulcer develops. These ulcers are covered with a grayish white membrane and vary tremendously in size and depth, although they are usually shallow and no greater than 0.5 cm. in diameter. A moderate amount of tenderness and pain is present. The breath is foul. Secondary involvement of the cervical lymph nodes draining the area usually appears, but suppuration in the nodes is uncommon. The disease is usually of short duration, rarely presents a systemic reaction, and usually terminates in 8 to 16 days. Penicillin is most effective; large doses may be necessary. If this agent is ineffective, intravenous neosalvarsan should be tried.

NOMA

This is a rapidly spreading gangrenous process occurring usually in the gums, cheeks, and mucous membranes of undernourished children between the ages of 2 and 10 years.



Fig. 19. Ulcer of thumb due to tularemia. The *patient, a 36-year-old female, suffered a punctured* wound at this point five weeks previously while cleaning a rabbit. Three days later she had a chill and developed fever. A few days after this, the *ulcer on the thumb appeared*. Fever persisted, accompanied by an occasional chill. Four weeks after onset the epitrochlear and axillary nodes enlarged and were incised later because of suppuration. The *patient's serum agglutinated the Pasteurella tularensis* in a dilution of 1:160. (St. Louis City Hospital.)

the disease. 2. In the *oculoglandular* type, the primary lesion is in the conjunctiva, occasionally being found as a papule associated with edema, redness, lacrimation, and photophobia. Ulcerations are not uncommon. The auricular, submaxillary, and anterior cervical lymph nodes may enlarge and become moderately tender and painful. 3. A *glandular* type without evidence of a primary lesion is occasionally seen. In other respects, however, the symptoms and signs do not differ from those observed in the ulceroglandular type. 4. A *typhoid* type producing fever without a visible primary lesion or lymphatic involvement is uncommon. 5. The *pulmonary* type as a primary entity is quite rare but pulmonary infection is commonly encountered with other types of the disease, particularly the ulceroglandular type. 6. The *ingestion* type results from eating inadequately cooked infected rabbit meat. Diffuse pain in the abdomen, diarrhea, nausea, vomiting, and fever are usual symptoms of this type of infection; enlargement of the submaxillary and cervical lymph nodes is common. Moderate leukocytosis is usually present.

The Foshay test, consisting of the intradermal injection of a *P. tularensis* vaccine, is very accurate and is positive from the second day of the disease up to about 18 months. Unfortunately, the organism cannot be identified in smears from the ulcer; moreover, *P. tularensis* will not grow on the media routinely used for culture, but will grow in blood-glucose-cystine media. Guinea pigs can be infected readily with exudate and tissue from an infected case.

Antibiotics, including Streptomycin, Terramycin, and Aureomycin, are quite effective in treatment (14, 15). When suppuration appears at the site of infected lymph nodes, incision is indicated; drainage usually persists for many days or even for weeks.

RABIES

Rabies or hydrophobia is a spasmophilic or paralytic disease caused by a virus and contracted by the bite of a rabid animal. The dog accounts for more than 90 per cent of the human cases, but wolves, cats, badgers, and other animals may become infected and may also transfer the infection by their bite. Almost all animals, including horses and cows, are susceptible and may contract the disease if bitten by rabid animals. Although the disease is less prevalent now than it was 50 or 100 years ago, it will probably always be a menace as long as misdirected human kindness allows the stray dog to roam the streets and countrysides.

The greatest problem in rabies is determining whether or not the offending animal is rabid. This is usually not difficult. Healthy dogs are apt to bite but usually are guilty of this offense only during the excitement of play or while being tormented. The actions of a rabid dog are rather typical. The usual story is that the dog, a stray animal, deliberately ran up to the patient, bit him, and rapidly disappeared. If an attempt is made to follow these animals, it will usually be learned that more people have been bitten by the same dog. It is of extreme importance, then, that any dog that bites a person without provocation should be caught and confined under observation for 10 to 14 days. If the animal is rabid, serious symptoms (e.g., paralysis) will almost invariably develop within 48 hours. The onset of the disease in the animal is characterized by a restlessness and an im-

strated a spirochete (*Spirillum minus*) as the etiologic factor in the more common type known as Sodoku. A less common type known as Haverhill fever is caused by *Streptobacillus moniliformis*. About the same time the fever and associated symptoms develop, the scar at the site of the bite breaks down, ulcerates and a regional lymphadenopathy develops. The symptoms, which may include fever, nausea, vomiting, and pains in the joints and muscles, may be quite severe, resulting even in delirium. Fatalities, however, are uncommon. During the attacks a rather typical erythematous, macular rash with lesions as large as 1 to 2 cm. in diameter may develop. The attacks usually persist for two to three days but recur again in four to six days over a period of several months unless treatment is instituted. The spirochete may frequently be found in the blood, skin lesion, or lymph node of the patient, but it is more consistently found in the blood of a mouse injected with the blood of the patient.

Antibiotics should be effective in most cases. Altemeier and associates (17) have noted that the type caused by the streptobacillus responds to penicillin. Neosalvarsan is quite specific for the spirochetal type and should be tried if antibiotics fail.

ANTHRAX

A century or two ago anthrax was a miserable scourge in European countries, but during recent years it has become uncommon, especially in the United States. The causative organism, *Bacillus anthracis* (an aerobic, gram-positive, spore-forming bacillus), was isolated by Davaine in 1850. The disease is also known as malignant pustule or woolsorter's disease. Infection may be acquired by handling wool or hides from various animals, including sheep, cattle, horses, hogs, guinea pigs, and rabbits. In a few instances the source of infection has been found to be a newly acquired shaving brush.

There are three types of the disease: 1. The *cutaneous type*, which is associated with a low mortality, usually manifests itself as a furuncularlike lesion with a black necrotic center. 2. The *pulmonary* form of the disease is rare and presumably results from inhalation of the spores. The patient rapidly becomes very ill, develops chills, fever, prostration, tachycardia, cough, and pulmonary edema, and practically always dies within a few days after onset. 3. The *intestinal* form manifests itself by chills, fever, diarrhea, and vomiting and is associated with a high mortality.

The disease responds to penicillin, but, since an antitoxin is known to be effective, it should be given simultaneously. The lesions should not be incised because operative trauma seems to encourage development of bacteremia.

TYPHOID

Fortunately, typhoid fever is now a rare disease. Complications are common; most of them are surgical. *Perforation of an ulcer of the ileum* is perhaps the most common. Manifestations of the resultant peritonitis are atypical and consist of tenderness (without significant muscle spasm), increase in the distention, nausea, and occasionally vomiting. X-ray should reveal air under the diaphragm. Emergency operation is, of course, indicated. *Gallbladder disease including cholelithiasis* may be secondary to the disease. Typhoid carriers usually have infected gallbladders and/or "infected" gallstones, removal of which is curative on most occasions; "infected" gallstones may also be present in the common duct. These must also be removed in order to free the carrier of his hazard to others. *Osteomyelitis* and *chondritis* occur occasionally but are usually very insidious. Aureomycin should be given for all the complications since it is fairly specific for typhoid fever.

AMEBIC DYSENTERY

The primary lesion produced by *Endamoeba histolytica* (Fig. 21) is colitis, which develops as widespread ulcerations involving particularly the cecum, the ascending colon, and the upper rectum. The disease can usually be recognized by proctoscopy and microscopic examination of smears, which almost invariably will reveal amebae. Symptoms include abdominal pain (usually of a cramplike type), diarrhea, and occasionally nausea and vomiting. Accordingly, it may resemble the onset of acute appendicitis for which appendectomy may be performed. Such a

It is also known as cancrum oris or gangrenous stomatitis. Vincent's fusiform bacilli and spirochetes are frequently found in the tissue, but the exact causative organism is not known. Antibiotics, including penicillin particularly, should be tried. During recent years this disease has become extremely uncommon.

LUDWIG'S ANGINA

In 1836, Ludwig of Stuttgart described an acute, deep-seated infection involving the floor of the mouth and upper portion of the neck. Although the infection practically always remains localized in the floor of the mouth and upper part of the neck, constitutional symptoms, including fever, usually are present. The organism most frequently obtained on culture is a streptococcus, but other mouth organisms may be found, sometimes singly, but at other times apparently growing in a symbiotic manner. Anaerobic organisms undoubtedly play an important role in the development of the disease. The most common source of the infection is an alveolar abscess which ruptures through the inner table of the mandible (Ivy). The infection may arise from dental caries or other causes, but frequently no primary lesion can be discovered.

The induration and swelling of the floor of the mouth develop rapidly and are associated with pain but with a variable amount of tenderness. As the swelling increases, the tongue is pushed upward and backward, thereby holding the mouth open and interfering with swallowing and breathing. Redness of the skin does not appear until late. Fever is usually present as are also constitutional symptoms such as prostration and tachycardia, at least to a moderate degree. Edema of the glottis and bronchopneumonia are common and serious complications, especially in neglected or untreated cases.

Usually, the infection responds quite well to antibiotics; if not, radical incision will be indicated (Fig. 20). Even though very little, if any, pus may be found, incision appears to result in marked improvement. If at any time edema of the glottis or larynx occurs, a tracheotomy should be performed without delay. Too often, tracheotomy is not performed in time to be the lifesaving procedure that it should be.

RAT-BITE FEVER

Although it has been known for many years that a prolonged illness with intermittent attacks of fever may develop in the human being 10 to 22 days following a rat bite, it was not until 1916, that Futaki and associates demon-



A



B

Fig. 20. Ludwig's angina. A, note how the tissues open up after proper incision; B, same patient eight days after operation. As soon as the induration subsides, the flaps drop back in their normal positions. (From Blair and Ivy. Essentials of Oral Surgery, C. V. Mosby.)



Fig. 22. Echinococcus cyst. This cyst was removed from the ventral surface of the liver in a man who was raised in Italy. Incision through the wall reveals numerous daughter cysts.

developed; these are in turn converted into cysts identical to the original or mother cyst. Such daughter cysts also form granddaughter cysts, which are contained within a thick outer mother-cyst wall (Fig. 22).

The cysts enlarge and develop insidiously without many clinical manifestations. Rarely are systemic symptoms encountered. When the cyst is located in the liver, a mild, rather constant pain, similar to that produced by chronic cholecystitis, but without much dyspepsia, is experienced. Sometimes the cyst is palpable upon abdominal examination. If the cyst is in the lung, symptoms of a benign tumor, such as cough, mild pain on respiration, and dyspnea, may develop. Bone is not infrequently the site of invasion. Casoni's intradermal test* is usually considered the most important diagnostic procedure, although the echinococcus fixation test† of Weinberg is reliable. Both of these tests may give negative results when no absorption from the cysts is occurring. An eosinophilia is often present.

Unless inaccessible, the cysts should be re-

* Casoni's intradermal test is dependent upon sensitivity, as is the tuberculin test. A small quantity of fluid obtained previously from a known cyst is injected into the skin. A local reaction results if the patient has echinococcus disease.

† The complement-fixation test of Weinberg utilizes an antigen made from fresh hydatid fluid containing scolices. The test is performed on the patient's serum. The antigen required in this test may be obtained from some pharmaceutical houses.



Fig. 21. *Endameba histolytica.* Mobile forms showing ingested red cells, granules, and clear ectoplasm. (Army Medical School Collection, Washington, D.C.)

mistake happened on numerous occasions throughout the country during the time when the Chicago epidemic of 1933 was at its peak. Submitting the patient to an operation during the onset of amebic dysentery will result in many fatalities even though the actual condition is recognized and emetine therapy instituted immediately.

Perforation of an amebic ulceration is not common but does occur; the most common sites are the cecum and appendix. In the chronic stage of the disease, stricture may develop, but it is quite uncommon. Another rare but important complication of amebic colitis is an *amebic granuloma,* which may be several centimeters in diameter and therefore resemble a carcinoma. It is most common in the cecum and upper rectum. If it is located in the rectum, diagnosis can be made by biopsy, since the organisms are invariably present in the involved tissue.

Abscess of the liver is a frequent complication of amebic dysentery, but it usually occurs only in the untreated or inadequately treated cases. The typical symptoms and signs of abscess of the liver, including chills, daily intermittent fever, prostration, and sweating, are usually encountered. Drainage by operation is associated with a high mortality, whereas intensive treatment with emetine alone will often prove curative. Aspiration is permissible in the large abscesses (see Chap. 28).

In the *treatment* of amebiasis, several drugs are effective. One of the most important is chloroquine, which should be given in doses of 0.6 gm. by mouth daily for two or three days, followed by a dose of 0.3 gm. daily for two or three weeks. Of the other drugs utilized, perhaps diodoquin and emetine are the more important. Antibiotics are usually indicated because of secondary infection which is so common; this is particularly true of amebic abscess of the liver. Indeed, the superimposed infection is an important factor in the high mortality rate.

ECHINOCOCCUS DISEASE

Hydatid or echinococcus disease is caused by one of the smallest of tapeworms, *Echinococcus granulosus,* and is encountered occasionally in most regions throughout the world but appears to be especially common in Australia, South America, and Iceland. Most of the patients with echinococcus disease encountered in the United States are foreign-born. For a detailed discussion of this disease the reader is referred elsewhere (18). The disease is contracted from dogs which are the tapeworm's host and excrete the eggs in their feces. After ingestion of the egg by the human being, the larva is freed by digestion of the shell and burrows into the intestinal wall. From there it may be carried in the portal blood stream to the liver, where it may lodge or be carried to or through the lung and finally to such organs as the kidney, bone, and brain. After larvae have reached their destination, hooklets disappear and a cyst develops, from the wall of which buds are



Fig. 22. Echinococcus cyst. This cyst was removed from the ventral surface of the liver in a man who was raised in Italy. Incision through the wall reveals numerous daughter cysts.

developed; these are in turn converted into cysts identical to the original or mother cyst. Such daughter cysts also form granddaughter cysts, which are contained within a thick outer mother-cyst wall (Fig. 22).

The cysts enlarge and develop insidiously without many clinical manifestations. Rarely are systemic symptoms encountered. When the cyst is located in the liver, a mild, rather constant pain, similar to that produced by chronic cholecystitis, but without much dyspepsia, is experienced. Sometimes the cyst is palpable upon abdominal examination. If the cyst is in the lung, symptoms of a benign tumor, such as cough, mild pain on respiration, and dyspnea, may develop. Bone is not infrequently the site of invasion. Casoni's intradermal test* is usually considered the most important diagnostic procedure, although the echinococcus fixation test† of Weinberg is reliable. Both of these tests may give negative results when no absorption from the cysts is occurring. An eosinophilia is often present.

Unless inaccessible, the cysts should be re-

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† The complement-fixation test of Weinberg utilizes an antigen made from fresh hydatid fluid containing scolices. The test is performed on the patient's serum. The antigen required in this test may be obtained from some pharmaceutical houses.

moved as soon as discovered. If possible the entire outer cyst is removed, avoiding rupture if possible, because of the danger of implantation of the contents of the cysts. Another undesirable feature of rupture of a cyst during its removal is the possible development of a sensitivity which may result in an anaphylactic reaction if a second operation is required and another cyst ruptured. In any event, if a subsequent operation is required for removal of more cysts, it is desirable to give hydrocortisone or cortisone on the day of operation to prevent an anaphylactic reaction. When in the liver, it is usually impossible to remove the outer cyst wall because of the danger of hemorrhage. Under such circumstances, the contents should be removed without peritoneal contamination, if possible, and 4 per cent formalin or tincture of iodine should be painted on the wall of the cyst to destroy the membrane. If all the cysts are removed and the lining of the mother cyst is destroyed, recovery should be uneventful and permanent (Fig. 22).

GRANULOMA INGUINALE

In 1905 Donovan described an intracellular microorganism which, on a stained (Wright) smear obtained from the lesion, shows up as a small, round, pink body with a blue-staining coccoid center. He associated the organism (*Donovania granulomatis*) with granuloma inguinale, but it is not agreed that this is the etiologic factor. The disease is of venereal origin, occurs more often among Negroes, and was originally described as a tropical disease, although it is encountered occasionally in temperate zones as well. In males, the lesion usually starts on the penis or scrotum, but frequently the initial lesion is in the groin (Fig. 23). In females, the lesion is first seen on the vulva, perineum, or groin. The disease starts as an indurated papule which ulcerates and slowly involves the adjacent skin. The granulating tissue of the ulcer is elevated, especially at the edges, appears red, and seldom reveals a necrotic base. Occasionally healing occurs in the center, either as a rough scar or combined with epithelization made possible by islands of epithelium which escaped destruction by the ulcer. At times the entire penis may be destroyed if treatment is not started in time. The lesion remains superficial and shows no tendency to develop sinuses or to invade the lymph nodes. The ulceration produces a thin milky secretion which at times has a characteristic sour fetid odor. Very little pain or tenderness is present. Occasionally the disease spreads toward the anus and produces a fungating, somewhat papillomatous lesion.

In therapy, aureomycin or terramycin should be tried first. If these agents are not effective, tartar emetic should be given, since it is fairly specific for this disease; a dose of 3 to 5 ml. of a 1 per cent solution should be given every three or four days and increased

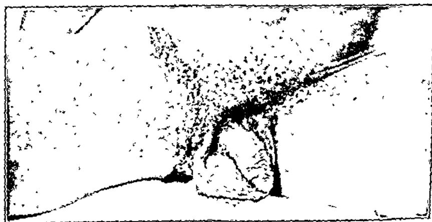


Fig. 23. Granuloma inguinale. The lesion, in a 45-year-old colored male, was cured by the administration of tartar emetic but recurred a few months later. The recurrent lesion was not as extensive as the original ulceration but responded scarcely at all to tartar emetic and various other types of therapy.

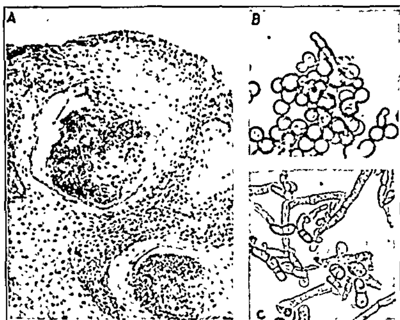


Fig. 24. Blastomycosis. A, minute blastomycotic abscess (low power) in skin at border of lesion illustrated in Figure 25; B, appearance of blastomycetes suspended in saline after first culture (high power); C, after several subcultures; note the mycelial formation. (From Cole. Ann. Surg.)

to 8 or 10 ml. as tolerated. Treatment should be continued until the patient has received 12 to 15 injections. Meticulous cleanliness is also important; hospitalization in stubborn cases for frequent irrigation is sometimes advisable.

BLASTOMYCOSIS

This disease was described independently in 1894 by Gilchrist and by Busse as being caused by a yeastlike organism, *Blastomyces dermatitides.* This organism multiplies in the tissue by budding, but develops mycelial threads (19) when growing in culture (Fig. 24). The cells are about 8 to 10 μ in diameter and are readily identified by the double refractile capsule. They have no nucleus, but the protoplasm contains coarsely granular material with refractile bodies. The organisms are most readily found by application of a small drop of 10 per cent sodium hydroxide to some pus under a cover slip in a fresh unstained preparation.

The lesion usually becomes implanted in the skin by a minor injury and manifests itself either primarily as an ulcer at the site of the inflicted wound or as a papule which breaks down and forms an ulcer. This ulcer starts originally as a local lesion and soon assumes characteristics which in appearance can be confused only with one other disease, lupus vulgaris (tuberculosis). The surface of the lesion is ulcerating, is raised above the adjacent skin, and assumes a cauliflowerlike or papillomatous appearance (Fig. 25). Along the edges of the ulcers may be found tiny pinpoint abscesses which sometimes may be seen only with the aid of a lens. The organisms are most readily found in these tiny abscesses. This lesion may remain local for one to two years, but it tends to become systemic partly because of autoinoculation but more especially because of metastatic implantation by the organism. The lungs are usually the first to become secondarily infected. Occasionally the infection is primary pulmonary. From the clinical and radiologic standpoint the infection of the lung cannot be distinguished from tuberculosis, but the organisms may be found in the sputum. Almost any organ in the body may become infected. The diagnosis is confirmed by finding the organisms, but when there is doubt, the patient should be tested with the antigen, blastomycin.

Treatment is so unsatisfactory that very few patients who develop the systemic disease ever recover. Unless the local lesion is seen or recognized early enough to permit complete excision, it will lead to a systemic in-

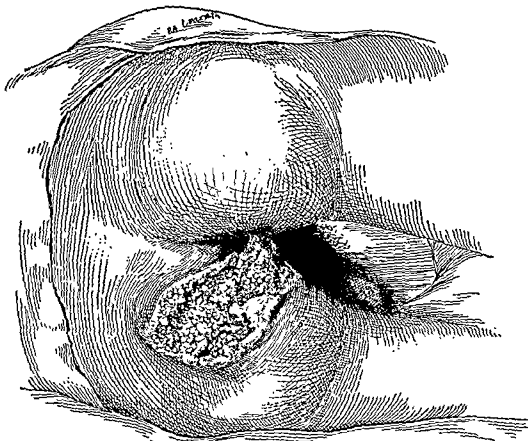


Fig. 25. Blastomycosis. Note the cauliflowerlike surface. The patient, a young man, suffered an injury to a finger while working in a mine. This ulcer failed to heal. Several months later lesions developed in the skin at numerous places over the body, including the buttock as shown above. In spite of various types of therapy, including administration of potassium iodide, x-ray therapy, and local medicinal application, the patient slowly failed and died two and a half years after onset. (Drawn from Cole. Ann. Surg.)

fection. Accordingly, we then *emphatically recommend excision* if the disease has not spread systemically. Stilbamidine and propamidine (aromatic diamidines) have been reported by Schoenbach and associates (20) as being quite effective in this disease. *Sodium iodide in large doses is helpful* but by no means curative.

CHANCROID

A chancroidal ulcer is of venereal origin, appears either on the penis, vulva, or vagina, and is caused by the Ducrey bacillus (gram-negative) which was isolated in 1889. The disease is autoinoculable and for that reason may occur as multiple ulcers. Diagnosis can usually be made readily by the presence or *history of a large primary ulcer on the genitals* associated with a painful and tender lymphadenitis in the groin. The use of Dmelcos vaccine, which is a suspension of killed Ducrey bacilli, as a diagnostic test may be extremely helpful in doubtful cases. In this test 0.2 ml. of the vaccine is injected intracutaneously in the forearm; a local reaction (papule or pustule) 48 hours after injection is a *positive* test. Four to eight days after exposure, a tiny *pustule appears which develops into an ulcer* (Fig. 26) several days later. From the ulcer, the edges of which are soft, friable, irregular, and slightly undermined, a foul profuse discharge appears. The primary lesion heals within two to four weeks, but unilateral or bilateral inguinal lymphadenitis (bubo) usually develops. Differentiation from venereal lymphogranuloma has been discussed on page 113. *Frequently, secondary infection is* shown by an increase in the acute inflammatory reactions; pyogenic bacteria will be obtained from the pus on culture. Culture of the causative organism from the ulcer requires special technic. Frequently, aspiration of the

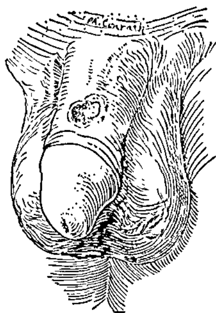


Fig. 26. Chancroid of the penis. The ulceration may be widespread, multiple, and on rare occasions very destructive.

pus in the suppurating lymph nodes is sufficient to allow the process to subside. At other times, incision and drainage is necessary. Treatment with sulfathiazole or sulfadiazine is quite effective. Antibiotics may be tried, but the disease is resistant to penicillin.

RARER TYPES OF MISCELLANEOUS SURGICAL INFECTIONS

Coccidioidal Granuloma. The causative agent is a yeastlike organism which reproduces by sporulation, in contrast to the blastomycete which reproduces by budding. When the sporozoites are mature they escape to the outside by bursting through the capsule. The disease was apparently first described by Wernicke in 1892. The organism produces nodules or a pustular, granulomatous eruption anywhere on the skin. Various organs of the body are invaded in a manner similar to blastomycosis but perhaps with more resemblance to tuberculosis. It was originally thought that the disease was universally fatal, but it has been noted recently that cures or survival for many years are common. In this country most of the cases are seen in California and Texas. It was commonly observed among troops training in California for desert warfare during World War II. The pulmonary type predominated, but, contrary to expectations, the mortality was low, influenced perhaps by early treatment and minimizing exposure. Diagnosis may be aided by the antigen coccidioidin. No medical agents are very effective in therapy.

Sporotrichosis. The etiologic factor is *Sporotrichum schenckii,* which may readily be found in smears of pus obtained from the lesions. The characteristic feature of the disease is the formation of soft, mildly inflamed nodules which appear in a chainlike fashion along the course of the lymphatics, particularly of the arms and legs. These nodules vary from 0.5 to 1 cm. in diameter and may break down and suppurate. A primary lesion may be absent but, if present, may readily be confused with tularemia. Few constitutional symptoms appear, but occasionally bone may be involved. The oral administration of potassium iodide, increasing the dose to 150 or 200 drops of saturated solution per day is very efficient in eliminating the disease.

Cryptococcosis (Torula Meningitis). In 1916 Stoddard and Cutler reported a group of patients with symptoms suggesting brain tumor or tuberculosis meningitis but in whom autopsy findings revealed an unusual type of meningitis caused by a yeastlike organism, *Cryptococcus histolyticus* (*Torula histolytica*). The organisms vary tremendously in size. Some are doubly contoured. The larger ones contain a dark-staining chromatinlike substance which resembles a nucleus. Reproduction is by budding. The organism attacks the brain by producing a thickening of the piarachnoid associated with tiny vesicular nodules containing clear liquid material. Larger caseous nodules may often be found within the brain itself. In one of the three cases observed in Barnes Hospital, St. Louis, an ulcer of a toe (Fig. 27) had been present several weeks before development of the cranial symptoms and apparently was the primary lesion. If an ulcer is present, the diagnosis can usually be made by finding the fungus on smear, by culture, or animal inoculation. No effective treatment is known. Broad spectrum antibiotics should be tried.

Yaws. With manifestations similar to syphilis, this disease is likewise caused by a spirochete (*Treponema pertenue*). The response to the serologic tests is almost identical to

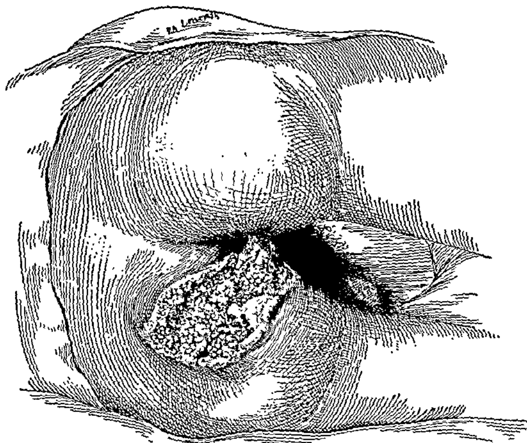


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injury or abrasion. They may occur at the site of penetration of larvae such as hookworm or strongyloides associated with secondary infection. In some cases the abrasion can be traced to the myiasis-producing fly which deposits its eggs under the skin; in a variable number of weeks, depending on the type of fly, the larvae burrow to the exterior and produce an ulcer which is apt to become secondarily infected. The initial lesion is painful and papillomatous in character, becomes necrotic, and ulcerates. These ulcers may become multiple and enormous in size; they heal slowly and usually with a deforming scar. Penicillin and a well balanced diet are quite effective.

The type of ulcer designated as Oriental Sore (also known as Delhi Boil, Bagdad Boil, and so forth) is caused by *Leishmania tropica* and is transmitted by sandflies (*Phlebotomus papatasiiand Pisergenti*). It is encountered in tropical regions of both hemispheres. After an incubation period of several weeks or months, a small indurated crusted nodule appears at the site of the bite, usually on the exposed parts of the body, and, within a period of several weeks, progresses to ulceration. Multiple lesions are common. Likewise, secondary infection is common and may increase the size of the ulcer, as well as its symptoms. The uncomplicated sores heal within 2 to 10 months but leave depigmented scars, often with retraction and deformity. A fairly solid immunity follows this infection. Treatment consists of injection of quinacrine and berberine sulfate around the ulcer; sodium antimony gluconate should be given parenterally. If secondary infection is extensive, penicillin or a similar antibiotic should be given.

Histoplasmosis. Histoplasmosis has been recognized only comparatively recently, but, in view of its similarity to certain infections (particularly tuberculosis), it is probably an old disease. The causative organism is the fungus, *Histoplasma capsulatum,* which grows readily in proper media. Since histoplasmosis is air-borne, the pulmonary system is most frequently involved. Fever, occasional chills, cough, sweating, malaise, headache, arthralgia, and myalgia are apt to begin 10 days to 3 weeks after inhalation of the fungus. In the acute stage, pulmonary findings are minimal. Other manifestations such as ulcers (in the mouth, pharynx, or intestine), weight loss, and anemia may develop. The appendix may also be involved and produce manifestations of appendicitis. Enlargement of the liver, spleen, and lymph nodes likewise is common. Bone may be affected, in fact, so commonly, that bone-marrow aspiration will reveal presence of organisms in a high percentage of cases. In advanced cases, cavities form in the lung; on such occasions, the disease is difficult to differentiate from tuberculosis except by the tuberculin and histoplasmin tests. The antigen, histoplasmin, originally prepared by Christie and Peterson (23) (obtainable from the National Institutes of Health), as well as a recently devised complement-fixation test, is quite accurate in diagnosis. The disease is most commonly seen in children and young adults in the central states. In the mild form, it occurs as diffusely calcified nodules in the lungs, as revealed by x-ray. With the use of histoplasmin and culture methods, the diagnosis can usually be made if the disease is suspected. There is no specific agent for treatment although mycostatin, amphotericin and ethyl vanillate should be tried (24). Even without treatment most patients recover, although the illness may extend over a period of many months.

Nocardiosis. This is a term applied to various diseases caused by some species of the genus *Nocardia,* which are gram-positive rods with branching filaments; they are of the family Actinomycetaceae. The organisms occur freely in nature, but not all are pathogenic to man. *Pulmonary nocardiosis* resembles tuberculosis clinically and roentgenologically. The organisms may attack the brain, bones, and, in fact, almost any organ of the body.

Madura foot may be classified as a nocardial infection; it is caused by *Nocardia madurae.* The characteristic lesions are slowly forming nodules which occur usually on the plantar surface of the foot. These nodes become soft and later form sinuses which penetrate so deeply as to involve any of the bony or soft tissues of the foot; amputation may be required. While madura foot (mycetoma) is encountered chiefly in the Orient, especially among poorly nourished Indians, it does occur in the temperate zones. The diagnosis may often be made by finding the organ-

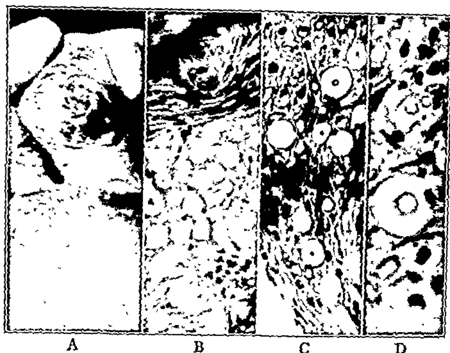


Fig. 27. Torula. A, photograph of the under surface of the second toe, showing the ulcer due to torula. Patient died four months later, six months after the appearance of the ulcer and the development of symptoms typical of torular infection of the brain; B, C, and D, microscopic section (high power) of the ulcer, which was excised, revealed many torula organisms which characteristically vary considerably in size, staining qualities, and so forth. D is slightly higher power than B and C, and shows the doubly contoured characteristic which is frequently noted, thereby simulating a blastomycete.

syphilis. It is not a venereal disease; infection usually occurs through a wound of the skin. The disease is common in Africa, India, and parts of South America but is rarely seen in this country. Primary, secondary, and tertiary stages are encountered with ultimate invasion of many organs, including bone, unless treatment is instituted. Arsenic in the form of salvarsan or neosalvarsan is specific, but penicillin is equally effective.

Leprosy. This disease was a serious scourge centuries ago, but it is rarely seen now except in the leper colonies. The most common lesion is a hyperemic nodule of the skin which may suppurate and produce prominent deformities because of cicatrization. On rare occasions, entire fingers or toes may be destroyed by the ulcerative process. Numerous internal organs may become affected. The disease resists treatment and may condemn the patient to isolation for the duration of his life. The victims usually live for years but may die from intercurrent infection. Patients with the disease should be isolated, although the contagious quality of the disease has been greatly exaggerated.

Numerous medicinal agents including the newer antibiotics are being utilized in therapy with variable effect, but none is specific.

Mycosis Fungoides. This is a chronic granulomatous disease possibly of parasitic origin which manifests itself as soft reddish nodules on the skin. These nodules may disappear or ulcerate with the production of a fungoid tumor. Lymph nodes and internal organs may become involved. The mortality is high.

Tropical Ulcers and Sores. These lesions are of numerous types; the etiology of many is poorly understood. However, most authorities (21, 22) in tropical medicine prefer to divide them into two major types: (1) Tropical Ulcer and (2) Oriental Sore.

The so-called Tropical Ulcers are of uncertain etiology. They may be caused by numerous bacteria particularly the spirochete (*Treponema vincenti*) and the fusiform bacillus (*Bacillus fusiformis*). They are chronic, progressive sloughing ulcers usually seen on the lower extremities. The size varies greatly often reaching 5 to 10 cm. in diameter. These ulcers commonly develop at the site of an

8

ULCERS AND GANGRENE

CARL MOYER

Ulcers
Gangrene

Ulcers, or sores, and gangrene are intimately related. All ulcers excepting those that follow the avulsion of tissue are preceded by necrosis or gangrene of the skin.

Gangrene once implied massive necrosis of tissue but now necrosis of any part of the living body may rightly be called gangrene. Nonetheless some practical distinction still remains: the ulcer follows limited gangrene while loss of life or limb still attends massive necrosis or gangrene.

Clearly the causes of gangrene and ulcer are identical: namely, trauma, infection, and inadequate nutrition of a part of the body by virtue of impedence of blood flow or hemic abnormalities. However, because the therapeutic problems posed by massive necrosis and ulcers differ so much, this chapter is divided into two parts, Ulcers and Gangrene.

Excepting for the self-inflicted traumatic ulcer, the factitious ulcer, the relationship of trauma to gangrene and ulcer will be discussed in the section on Gangrene.

ULCERS

Although much has been written about the specific appearances of certain ulcers, excepting for a few, such as the relatively rare blastomycotic, maduromycotic, tularemic, and chromoblastomycotic ones, there is often nothing characteristic about them. The neoplastic ulcer may have a relatively clean granulating base without a rolled-up edge, the stasis ulcer may have an appearance varying from a pale avascular base with heaped-up edges to a highly vascular base with flat edges; the same is true for the arterial occlusive ulcers. The determination of the cause of an ulcer must rest upon the discovery of specific objective evidence and not upon its gross appearance.

Because the proper treatment of an ulcer primarily depends upon the solution of the problem of its *genesis*, the determination of the nature of an ulcer is most important. Occasionally, this is difficult unless an orderly approach to the problem is made.

The parts of the history and the examinations of the person that are particularly pertinent to the ulcer problem are as follows:

History:

1. Relationship of the onset to injury, cold, heat, general illness, and to thrombophlebitis.
2. Medications used particularly locally.
3. Occupation, especially in regard to the handling of animals, animal products, exposure to cold in refrigerators as well as outdoors.
4. Foreign travel and length and nature of sojourn.
5. Patient's description of the local lesion before the ulcer occurred.
6. Ascertainment of the characteristics of the pain and amount of itching.

Examination:

1. Culture
   a. for corynebacteria on Loeffler's and tellurite media.
   b. for hemolytic streptococci and coagulase-positive and hemolytic staphylococci.
2. Biopsy of edge and base of ulcer.
3. Determination of patency of arterial system (oscillometry and angiography when any peripheral pulses are absent).

ism in the discharge from the sinuses in the foot. In this country at least, the chief importance lies in its similarity to tuberculosis and other chronic osteomyelites of the foot.

Treatment of most types of nocardiosis is unsatisfactory. However, some types respond to chloramphenicol and sulfadiazine. Very large doses of penicillin should be tried.

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tibacterials will, in some sensitive individuals, maintain the ulcer. Coal oil (kerosene), turpentine, and tar, still used as home-remedies for itches, rheumatic pains, and insect bites, are other chemicals that are capable of making an ulcer out of an otherwise simple cut or abrasion.

The treatment of a factitious ulcer is usually simple: Remove the cause. However, at times, the ulcer has existed for so long that its base is so avascular that excision of the ulcer and skin grafting are needed to cure it.

Bacterial Ulcers. Globally, bacteria, fungi, and protozoa constitute the major causes of ulcers. However, in the United States and Canada they are not as important etiologically as they are in Asia, Africa, and tropical America. Nonetheless one should be more mindful of the roles that they play in the genesis of ulcers because of the facilitation of travel and the increasing temporary abode of many of our people in Asia, Africa, and tropical America.

Corynebacterium diphtheriae, Pasteurella tularensis, and anaerobic streptococci are important causes of cutaneous ulcers. Corynebacterial infections of wounds of the legs in the tropics produce chronic Tropical Sores and in the temperate zones ulcers that are almost uniformly mistaken for stasis ulcers. Chronic diphtheritic ulcers have no specific characteristics and are not as a rule attended by systemic illness. The only means of detecting them is by the routine culturing of the exudate from all chronic ulcers on Loeffler's and tellurite media. The discovery of a positive culture should be followed by virulence tests. The treatment of a diphtheritic ulcer consists of meticulous cleanliness and antitoxin. Rigid aseptic precautions are important and, if in a hospital, the patient must be isolated.

Tularemic ulcers are small, 0.5 to 1 cm., and heal spontaneously within three to six weeks (p. 121). They occur at the sites of inoculation of the organism. Inoculation may be effected through an abrasion or cut of the hand while skinning or cleaning infected rabbits or ground squirrels and by the biting deer-fly or tick. The ulcer develops rapidly and is peculiarly painful. The lymph nodes in the lymphatic drainage area of the inoculation site enlarge rapidly and painfully and are prone to suppurate. The systemic illness, though usually marked, may be very slight. Diagnosis before the third week of the illness depends upon recognition of the significance of the association of the small, painful ulcer and lymphadenitis of the regional lymph nodes, and the history. After the second week of illness, specific agglutinating antibodies appear in the blood. Streptomycin, 1 gm. daily, cures the disease. However, lymph nodes may suppurate and require drainage when streptomycin is started later than the third day of the illness.

The anaerobic streptococci that are a part of the normal bacterial flora of the mouth and gastrointestinal tract occasionally cause peculiar chronic ulcers (Fig. 2). Although the anaerobic streptococcal ulcer usually begins with an infection of an incision through the abdominal wall, it does follow even minor injuries to any part of the body. The chronic anaerobic streptococcal ulcer has purple, rounded margins with undermined edges (1) and sinuses that often communicate with satellite ulcers about it and occasionally follow intermuscular fascial planes and large blood vessels. It grows in size steadily unless properly treated.

The most effective treatment of the anaerobic streptococcal ulcer developed to date is the incision of the undermined margins and all sinuses, so as to permit loose packing of the whole of the infected zone twice daily with fine-meshed gauze impregnated with a suspension of activated zinc peroxide, and the administration of penicillin. Split-thickness grafts are often required to cover the cutaneous defects after the infection is controlled.

Acute ulcers associated with pyogenic bacteria (especially the streptococcus) may develop anywhere on the body, primarily on the lower extremity (Fig. 3). They are probably usually secondary to mild trauma which would heal uneventfully if contamination with a virulent organism had not taken place. They tend to heal spontaneously after the infection subsides. They are less common now than before the days of antibiotics.

Fungal Ulcers. *Blastomyces dermatitidis* (U. S.) and *B. brasiliensis* (tropical America) when introduced into injured skin or mucous membranes are capable of producing chronic ulcerative granulomas of the skin,

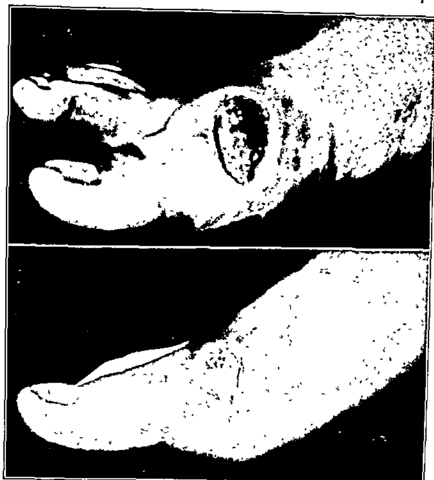


Fig. 1. Traumatic ulcer due to repeated chemical injury. The top figure shows an ulcer produced by daily application of carbolic ointment for four weeks following a small laceration of the foot in a girl eight years old. Below, within three weeks after elimination of the chemical irritation, the ulcer had healed.

4. Biopsy of skin and muscle at some distance from the ulcer whenever Raynaud's phenomenon is observed.
5. Red blood cell count.
6. Tests for red blood cell sickling in all Negroes with ulcers of the lower extremity.
7. Platelet counts on all persons having ulcers of the legs with deep pigmentation of the skin about the ulcer and around the entire leg.

The exercise of thought after ascertaining these things, and repetitive observation and reflection will unravel the etiology of most ulcers and permit the selection of the appropriate means of treatment.

Factitious Ulcers. Proving that an ulcer has a factitious (man-made) origin is frequently difficult more especially when the patient willfully makes it. The factitious ulcer has no telltale characteristics. It is usually chronic and located upon the anterior or lateral aspect of the lower extremity. Willful factitious ulcers are usually produced by the individual burning, rubbing, or scratching himself. The factitious ulcer is to be found most often among prisoners, the insane, and "professional workmen's compensation cheats." Because the ulcer is most frequently maintained by scratching with the fingernails, testing the debris beneath the fingernails daily for the presence of blood often provides a clue to the patient's actions.

The nonwilled factitious ulcer is much more common than the willed and is usually readily diagnosed. The history is most important: a scratch, cut, or insect bite upon which a salve containing a medicament or a home-remedy is placed is the usual beginning of such an ulcer. Salves containing phenol are especially potent ulcer producers (Fig. 1). However, ointments containing such things as picric acid, penicillin, Furacin, and other an-

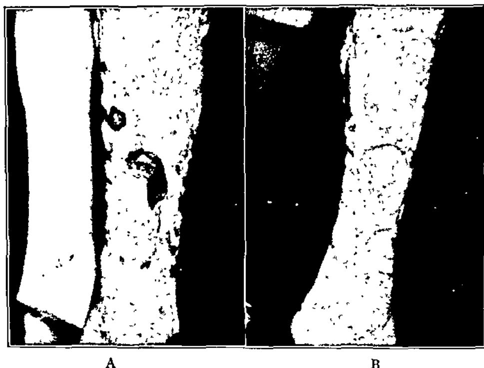


Fig. 4. Syphilitic ulcers of the leg; such ulcers are usually multiple. A, note the smooth, punched-out appearance of the edge of the ulcer. As happens occasionally, antiluetic treatment was ineffectual. B, appearance of leg three weeks after excision of the ulcer and application of skin graft.

sent local disease only and their removal is curative. Occasionally, a second excision may be required. X-ray therapy has been recommended and is fairly effective, but the treatment is prolonged (75 to 100 roentgen units filtered through 1 mm. of aluminum weekly for 12 to 15 weeks) and entails the danger of delayed carcinogenesis.

Miscellaneous Ulcers—Microorganismal. Granuloma inguinale having as its causative agent the Donovan body, a gram-negative nonmotile organism, is a *chronic ulcerative* destructive disease mainly of the crural regions and genitalia. However, lesions about the neck, hands, and face are frequent: rarely they are to be found upon the legs.

When not severely secondarily infected, the ulcer of lymphogranuloma is peculiarly painless. It bleeds very readily. The periulcerous *swelling often is great and has all of the* visible and palpable characteristics of chronic hard lymphedema.

Microscopic examination of a biopsy taken from the margin of the ulcer usually permits a ready diagnosis because of the typical intracellular position of the Donovan bodies in large mononuclear cells. However, even though the organism may not be found in the first biopsy, the exceedingly rich vascularity of the granulation tissue should prompt suspicion of the nature of the ulcer and biopsy repeated until the organism is found.

Streptomycin (4 gm. daily for 10 days to 3 weeks) is curative. Occasionally operative correction of scar contractures may be required after streptomycin has cured the disease.

The chronic, cutaneous, syphilitic ulcer is a manifestation of late syphilis and represents the breakdown of a cutaneous gumma. Consequently, a painless cutaneous tumor precedes the ulcer. The syphilitic ulcer is painless, sharp-margined (Fig. 4) and soon covered by a plush, healthy looking granulation tissue that accepts split-thickness grafts readily. After ulceration has occurred, diagnosis cannot be established with certainty by biopsy. Diagnosis largely depends upon clinical suspicion and the institution of a therapeutic trial. Any ulcer that is preceded by a painless tumor should be considered to be a leutic

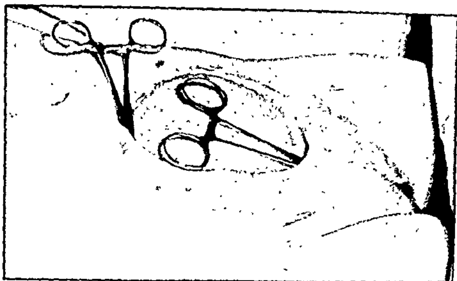


Fig. 2. Chronic undermining ulcer of Meleney, produced by a microaerophilic hemolytic streptococcus. The photo represents the ulcer on admission, one year after onset of illness. Note the extensive undermining extending into the vulva and into the flanks. The skin edges were rolled in. Counter incisions had been made in the groins. (From Meleney. Ann. Surg.)

and skin and oronasal mucous membranes respectively. In the United States, blastomycotic ulcers are found mainly upon the ankles, legs, feet, face, hands, and wrists. The ulcer grows slowly. Its margin is irregular, raised, and contains small abscesses having minute external openings exuding small amounts of pus. The central part of the ulcer heals, as the margin extends, and is covered by atrophic nonpigmented skin lacking accessory skin structures. The diagnosis is fairly easily made by biopsy of a part of the margin of the ulcer containing one of the small abscesses, culture of the pus from a satellite abscess on Sabouraud's media, and skin testing with blastomyces vaccine.

Excision of the entire ulcer and secondarily healed central area and immediate coverage of the cutaneous defect with a split-thickness skin graft after desensitization of the individual with blastomyces vaccine quickly cure most blastomycotic ulcers provided they are not associated with the systemic form of the disease. Fortunately, most of the ulcers repre-



Fig. 3. Pyogenic ulcers due to a streptococcus infection. The above photograph was taken five weeks after onset at the site of minute abscesses which failed to heal, presumably because of dependency and the virulence of the organism.

The protozoans *Leishmania tropica* and *L. braziliensis* are prominent causes of chronic cutaneous ulcers (Oriental Sores) in the tropics and semitropics wherever tropical sandflies exist. The disease is not established in the United States yet. However, cutaneous leishmaniasis has been seen in our port cities and should always be considered as a possible cause of a chronic ulcer on anyone having worked or lived recently in an endemic area.

The cutaneous lesion of leishmaniasis begins as a pruritic papule that grows and breaks down centrally. The ulcer is painless unless secondarily infected. Although the ulcer may attain a size of 5 to 6 cm. across, it usually heals spontaneously within a year leaving an unsightly scar.

The diagnosis of cutaneous leishmaniasis rests upon the discovery of Leishman-Donovan bodies in biopsies or smears of the local lesion.

The treatment of a single or a few simultaneous ulcers consists of curettage, freezing with carbon-dioxide snow or the local infiltration of a 1 per cent solution of berberine sulfate. Fuadin and Neostibosan (pentavalent antimonials) are reserved for the patient having multiple ulcers.

Verminotic Ulcers. Only two worm infestations are attended by cutaneous ulcerations: dracunculiasis and creeping eruption. *Dracunculus medinensis* (guinea worm) ulcers occur predominantly about the ankles and legs and are found wherever the proper *Cyclops* vector exists but especially in India and Africa. About 50 million people are infested. The female worm, about 1 yard in length and 2 to 3 mm. in diameter, lives beneath the skin of the foot and leg and burrows a hole through the skin to lay eggs. The ulcer begins with burning and itching and a vesicle which, upon becoming secondarily infected, ulcerates and persists.

The diagnosis may be attained by x-ray when the worms are calcified or the sinus is injected with a water-miscible radiopaque medium. The discovery of the typical larvae in the milky fluid that exudes from the ulcer after the application of a warm, wet dressing also establishes the diagnosis.

Antibiotics for the control of secondary infection and the slow winding of the worm upon a small, split piece of wood over a period of a fortnight constitute the safest therapy. Surgical excision of the worm is fraught with the danger of fulminant infection of the wound.

The ulcers that occasionally attend the cutaneous infestation with *Ancylostoma braziliense* (larvae of the dog and cat hookworms) are factitious in origin. The intense pruritis prompts destructive scratching by some sufferers.

The observation of telltale "worm tracks" in the skin and scratch marks about shallow ulcers should prompt immediate suspicion of the cause.

Killing the worms in the skin with an ethyl chloride spray or carbon-dioxide snow stops the trouble.

Vascular Ulcers. Vascular ulcers, with but few exceptions, are limited to the lower extremities. The most important vascular diseases that lead to their genesis are: 1. occlusions of major arteries by emboli, thrombi (arteriosclerosis), and endarteritis obliterans; 2. abnormalities of the veins (stasis ulceration), and 3. hemangiomata.

ARTERIAL OBSTRUCTIVE ULCERS. Although the predominant locations of ulcers relatable to the obstruction of major arteries are the toes and heel, they do occur about the malleoli and over the tibia up to the middle of the leg (Fig. 5). They are usually generated by such injuries as those caused by the rubbing of a bony prominence by a new shoe, the stubbing of a toe, the cutting of a corn or an ingrown toenail, or a bump to the shin. The injury is soon followed by a blister under which the skin dies and within three to five days turns into a dry, black eschar. The eschar separates slowly and after the passage of two to four weeks comes off leaving an indolent, painful, avascular ulcer that does not heal.

The arterial occlusive ulcer is often mistaken for a varicose or stasis ulcer especially when it is located about or above the malleoli and the person has visible varicose veins. Actually, varicose veins are to be found in about 20 per cent of elderly people having arterial disease; consequently, the nonetiologic or randomly unrelated association of varicose veins and arterial occlusive ulceration occurs rather frequently.

The diagnosis of arterial occlusive ulceration rests upon the demonstration of an ar-

ulcer, and a trial of the efficacy of the treatment with bismuth, arsenicals, and penicillin should be undertaken after ascertaining by biopsy that the ulcer is not neoplastic. Leutic ulcers usually heal very rapidly with the above treatment.

The rare indolent lesion of late progressive, nodular, cutaneous, syphilitic dermatitis may be mistaken for cutaneous blastomycosis because healing takes place in the center as the lesion spreads. However, late nodular, cutaneous syphilis has a characteristic raised serpiginous margin that does not contain the characteristic pustules or blastomyces, and consequently cutaneous blastomycosis and late nodular syphilis are readily differentiated.

Another spirochetal disease confined to the tropics that is attended by cutaneous ulceration is yaws (*Treponema pertenue*). The primary lesion of this disease is an ulcer that heals slowly, usually occurring on the legs; the so-called mother yaw. The ulcers of yaws may appear upon the soles of the feet (crab yaws), and when they do they are painful.

Rare causes of chronic cutaneous ulcers are: glanders, anthrax, staphylococci, chromoblastomycosis, and maduromycosis (see Table 1).

TABLE 1. Rare Organismal Ulcers

Disease and Organism	Development of Ulcer	Attendant Phenomena	Diagnosis	Treatment	Occupational Predilection and Predominant Location
Anthrax (malignant pustule) *B. anthracis*	Papule, vesicles, pustule, shallow ulcer with black central eschar	Wide edematous pruritic periulcerous zone, painless ulcer, moderate regional lymphadenitis	Culture and separation from nonpathogenic relatives such as *B. subtilis* by injection into mice	Penicillin	Raw-hide handlers, slaughter house workers, animal-hair handlers Hands, wrists, arms, rarely legs
Glanders (acute) Farcy (chronic) *Malleomyces mallei*	1. Acute form. chills, fever, severe illness, nodule at point of entry breaks down leaving painful ulcer 2. Chronic form: exacerbations and remissions of crops of painful ulcers and abscesses over the whole body	Miliary nodules forming abscesses and ulcers along main lymphatics draining the primary lesion, regional lymphadenitis	Biopsy, culture, serologic tests, skin tests, animal inoculation	Sulfadiazine; (penicillin and streptomycin are ineffective)	Handlers of horses, donkeys, mules Veterinarians Hands and arms
Chromoblastomycosis *Phialophora verrucosa* *Hormodendrum pedrosoi* *Hormodendrum compactum*	Slowly growing papule, warty ulcer, no constitutional symptoms unless secondarily infected	Nodular regional lymphangitis, elephantiasis, large cauliflowerlike masses about the ulcers	Mycologic identification from tissue scrapings and biopsy, culture on Sabouraud's medium	Excision; (effective drug therapy has not been developed yet)	Leg
Maduromycosis (madura foot) Variety of fungi, predominantly *Monosporium apiospermum* and nocardia	Nodules, small abscesses, swelling, small ulcers after rupture of abscesses	Sinuses, progressive enlargement of the afflicted member Painless	Biopsy, Gram's stain and mycologic identification	Excision of cutaneous lesions when unaccompanied by deep penetration Amputation	Foot and hand
Chronic staphylococcal ulcer (resembles botryomycosis of cattle)	Abscess ruptures or is drained and does not heal	None	Culture	Antibiotic to which the organism is not resistant	Legs, arms, buttocks, neck

are related to the stasis of blood in the part must also be viewed with suspicion, because the oxygen saturation of the blood in the veins draining a stasis ulcer is at least as high and often higher than that of the blood in the veins of the unafflicted limb. In short, we do not know the precise cause of the so-called varicose or stasis ulcer. However, recently, while excising chronic stasis ulcers in order to place skin grafts upon normal tissue to cure these ulcers, a number of interesting observations were made: 1. the superficial cutaneous lymphatics are noninjectable in the skin, often far removed from the ulcer; 2. the veins about and beneath the ulcer are abnormal in that they frequently contain thrombi and are extremely friable; and 3. bleeding from the skin is much more intense about the ulcer than it is 2 or 3 inches from it. The significance of these observations is unknown.

The establishment of a diagnosis of stasis ulceration requires that other causes of ulcers of the legs such as arterial occlusion, hematogenic disturbances, trauma, and specific infections be ruled out (2, 3). *The discovery of varices in the extremity bearing an ulcer does not establish an etiologic relationship between the ulcer and venous disease.* Stasis ulcers may be aggravated by arterial obstruction (Fig. 6).

The treatment of stasis ulcers cannot be stereotyped. The acute and subacute stasis ulcers without fibrosis in the base and beneath the skin of the margin, and without atrophy and deep pigmentation of the surrounding skin, usually heal very quickly after the stripping or excision of the varices of the leg and thigh. Before undertaking the stripping or excision of the veins one must make certain that there are no hemolytic streptococci or coagulase-positive staphylococci in the ulcer and that any erysipelatous inflammation that may have existed about the ulcer has disappeared. The clearance of periulcerous inflammation and dangerous organisms from the ulcer before removal of the varices usually can be effected quickly by cleansing the foot and leg with soap and water twice daily. Elevation of the leg if it is edematous is also helpful. Frequent changing of saline-wet compresses applied to the ulcer itself, and parenteral administration of an appropriate antibiotic, proven effective by sensitivity tests, should be employed. The application of antibiotics and digestives to the ulcer itself has not been proven to be more effective in securing bacterial cleanliness of the ulcer than simple cleansing with soap and water and the frequent changing of saline-wet compresses.

After the excision or stripping. elastic bandages or stocking supports should be worn until the ulcer is healed and the foot, ankle, or leg does not swell appreciably with walking, standing, or sitting. In addition, the feet

TABLE 2. Treatment of Chronic Stasis Ulcers

	Treatment				
	A	B	C	D	E
Number Treated	44	6	12	34	48
Number Free of Ulcer for 2 Years	4	1	6	11	37
Number with Recurrent Ulcer	40	5	6	23	11
Per cent Success (2 years)	9	16	50	32	77

Treatment A: Ligation, stripping, and excision of varices. Wearing elastic supports.

Treatment B: Ligation, stripping, and excision of varices. Wearing elastic supports and ligation and division of external femoral or popliteal vein.

Treatment C: Ligation, stripping, and excision of varices. Wearing elastic supports, ligation and division of femoral or popliteal vein, excision of the ulcer with a narrow margin of skin, and immediate skin grafting.

Treatment D: As for C, excepting that the femoral or popliteal vein was not ligated and divided.

Treatment E: Ligation, stripping, and excision of varices. Wearing elastic supports. Excision of the ulcer and all abnormal skin about it and immediate skin grafting.

$X^2 (C - D) = 1.18, P = > .2, < .3$
$X^2 (D - E) = 16.4, P = < .001$
$X^2 (C - E) = 3.5, P = > .05, < 0.1$



Fig. 5. Ulcer of the leg due to arterial (arteriolar) deficiency. Ulceration at this point had appeared, healed, and recurred at intervals for 10 years and had been present for one year at the time the above photograph was taken. The patient was a woman, aged 34 years. *Practically all the charcteristics of ulcer due to arteriolar disease as described in the text were present in this patient. Healing was finally* achieved by rest, heat, cleanliness, and application of a pressure bandage to the leg.

terial occlusion by oscillometric testing and femoral arterial arteriography. The diagnosis cannot be made with certainty by the exercise of ordinary diagnostic maneuvers such as the failure to feel pulses in the peripheral arteries, the testing for rate of capillary filling, the observation of the rate of growth of nails, and the distribution of hair. Neither can it be made on the basis of complaints that may be typical of intermittent claudication. In other words, one cannot assume that an ulcer is not related to arterial occlusion because varicose veins are visible; and, conversely, one cannot assume that an ulcer has an arterial occlusive basis from nonmensurable clinical observation; arteriography and oscillometry often are required to establish the etiology of a vascular ulcer.

The treatment of an arterial occlusive ulcer depends upon the location and extent of the occlusion. Removal of the obstruction by thrombectomy, endarterectomy, or the placement of a graft should be practiced whenever possible. In case the occlusion is too extensive or involves the divisions of the popliteal artery, making surgical correction impossible or its attempt excessively hazardous, the treatment must be directed toward the control of infection with antibiotics and meticulous cleanliness and the prevention of progressive thrombosis by the administration of heparin (100 to 150 mg. daily). Should clean granulation tissue appear and cover the base of the ulcer, a thin split-thickness graft will often take upon it and cure the ulcer for a time. However, unless the arterial occlusion can be removed or circumvented by an operation, the probability that an arterial occlusive ulcer will heal is less than 0.5. Often in such cases the ulcer enlarges, and gangrene of the toes and foot occurs, necessitating an amputation.

The treatment of an arterial occlusive ulcer as a chronic stasis or varicose ulcer is an inexcusable mistake.

THE STASIS ULCER. The stasis ulcer or varicose ulcer is likely misnamed. For many years, the theory of *blood reflux* through varicose veins was accepted as an adequate explanation for the genesis of stasis ulcers. However, recent measurements of the direction and speed of blood flow in varices have demonstrated that reflux or reverse flow is only an evanescent phenomenon and that blood flows upward at normal rates in varices after the individual stands awhile. The idea that the ulcers associated with varicose veins



Fig. 7. Extensive stasis ulceration and fibrosis. Left, Mr. G. W., aged 54, chronic stasis ulcer for 33 years beginning after thrombophlebitis of the left leg. The ulcer is circumferential and includes the dorsum of the elephantiasic foot. Amputation recommended to him but refused. Right, same foot and leg a year after completion of Treatment E of Table 2. Only a 1 cm. ulcer exists over the instep. This arose after he abraded it on a stirrup while riding wearing oxford shoes. This result is classified as a therapeutic failure in Table 2, Treatment E.

and legs must be washed daily. Nothing is more conducive to the recurrence of an acute stasis ulcer than a filthy foot and leg!

The treatment of a stasis ulcer having an avascular fibrotic base, fibrosis beneath the skin surrounding the ulcer, deep pigmentation or atrophy of the periulcerous skin, and lack of injectable superficial cutaneous lymphatics is another matter. A stasis ulcer having the above characteristics may be called chronic. Chronic stasis ulcers are usually found upon the legs of persons who have had thrombophlebitis in the deep veins (4, 5) or varices, or have had their common femoral veins ligated. The results of five methods of treating the chronic stasis ulcer are shown in Table 2.

The extent of the excisions practiced in the Treatment Forms C, D and E (p. 143) are shown in Figure 7.

Before undertaking the stripping, excision, and ligation of varices above and about the chronic ulcer and the wide excision of the ulcer itself, the same preoperative precautions and measures taken for the acute stasis ulcer must also be exercised.

The technical factors found to be important in the conduct of Treatment E are listed in Table 3.

TABLE 3. Technical Factors Important in Treatment E of Table 2.

1. Hemostasis with triple 0 chromicized catgut.*
2. Excision of the entire fibrotic base of the ulcer and surrounding inelastic or atrophic skin and in underlying subcutaneous fascia taking care to leave periosteum and peritendineum.
3. Immediate coverage of the entire defect with a thick partial-thickness autograft of skin.
4. Feet and legs kept upon the bed for 14 to 21 days.**
5. Wear elastic supports indefinitely.

* Nonabsorbable hemostatic sutures are prone to come through the graft even years after primary healing and recurrent ulceration is prone to occur at their points of egress.

** To permit the patient to hang the legs over the edge of the bed, to sit in a chair, or to walk before the fourteenth to seventeenth day is often followed by more or less confluent petechial hemorrhages beneath the graft with delayed dissolution of the graft that was "completely taken" on the eighth or tenth postoperative day.

What can be accomplished by applying the principles of Treatment E is illustrated in Figure 7.



Fig. 6. Stasis ulcer. Top, Mr. B., aged 69, had a chronic stasis ulcer for 20 years. The ulcer shown had not healed for five years. The dorsalis pedis, posterior tibial, and popliteal pulses were normal. The skin about the entire ankle was underlain by scar, depigmented, and atrophic. The extent of the cutaneous excision practiced in Treatment Forms C and D of Table 2 is outlined by the continuous inked line. Middle, a medial view taken during the operation before graft emplacement; bottom, a lateral view taken four weeks postoperatively. The middle and bottom pictures show the extent of the excision practiced upon this patient illustrating Treatment E, Table 2.

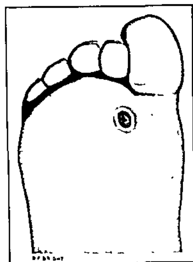


Fig. 8. Perforating ulcer of the sole of the foot in a man 70 years old. Such ulcers are deep and are frequently associated with a large amount of callus. They may occur in patients with arterial as well as with neurogenic lesions such as tabes dorsalis and diabetic neuropathy.

sociated with chronic perforating ulcers overlying the heads of the metatarsals, especially of the first, third, and fifth (Ch. 19, Fig. 4). These ulcers are called malperforant. They frequently constitute the site of origin of phlegmonous and other necrotizing infections of the plantar space and chronic septic arthritis of the metatarsal phalangeal joints followed inevitably by gangrene of the toes. For these reasons, the malperforant requires vigorous treatment. Before deep infection of a joint or plantar space occurs, the proper fitting of a metatarsal bar and daily careful washing of the foot, after securing healing of the ulcer by rest in bed and the careful removal of the surrounding callus, will prevent further trouble. In case the malperforant has extended into a joint as determined by gentle probing of its depths and x-rays, the only effective treatment is the resection of the joint and amputation of the attached phalanges.

Hematogenous Ulcers. Chronic ulcers of the lower extremity are occasionally associated with diseases of the blood such as chronic anemia (thalassemia minor, sickle cell anemia, and aplastic anemia), polycythemia, chronic thrombocytopenia, leukemia, and cryoglobulinemia. The hematogenic ulcers have no distinguishing characteristics and are often mistaken for stasis ulcers. The differentiation of the hematogenic ulcer of the lower extremity from the stasis, bacterial, fungal, and arterial flow deficiency ulcers rests upon clinical suspicion, the examination of the blood, and response to specific therapy.

A chronic ulcer upon the lower extremity of an anemic or thrombocytopenic person requires that specific examinations of the blood be performed to determine the cause of the anemia and thrombocytopenia, and that the hemic abnormality be overcome by appropriate treatment before undertaking surgical correction of the ulcer. To attempt the excision and grafting of hematogenic ulcers, or the excision or stripping of varices that may randomly attend them, before the anemia or thrombocytopenia is treated, only invites a recurrent ulceration that is often larger than it was before the surgical correction was attempted.

The chronic ulcer upon the lower extremity of a person having chronic leukemia or Hodgkin's disease is often peculiarly painful and difficult to treat. Even after restoration of the red blood cell volume to normal with transfusions and control of an excessively high white cell number, the ulcers fail to heal. In such cases, the application of thin split-thickness skin grafts to clean granulating surfaces cleared of hemolytic streptococci and coagulase-positive staphylococci, sometimes secures epithelial coverage. Before undertaking the grafting of an ulcer on a leukemic person, a search for cryoglobulins should be made, and a biopsy of the edge of the ulcer should be performed in order to rule out the remote possibility of the existence of leukemia cutis as its cause.

The rare chronic ulcer of the lower extremity associated with cryoglobulinemia mimics the stasis ulcer. However, the possibility that cryoglobulinemia might be the cause of the ulcer is usually suggested by the coexistence of Raynaud's phenomenon in the hands and the occurrence of the ulcer after exposure to cold. The rapid healing of the ulcer while the person is kept in a warm environment and the demonstration of cryoglobulins by electrophoresis practically clinch the diagnosis. However, the discovery of cryoglobulinemia should prompt an immediate search for leukemia, Hodgkin's disease, multiple myeloma, and the collagen diseases

Angiomatous Ulcers. A peculiar form of stasis ulcer is that which appears about the ankles of adolescents and young adults having angiomatous anomalies of the arteriovenous systems of the legs and thighs. Some of them have visible, diffuse, cutaneous, and cavernous hemangiomata; others do not. However, the bones of the afflicted part grow more rapidly than those of the opposite, normal limb, producing unilateral localized gigantism. Such cutaneous ulceration cannot be successfully treated unless the angioma is removable, and this is rarely feasible except by amputating that part of the limb containing the angioma. The removal of varices and the ligation of arteries to the afflicted part of the limb provide, at best, only brief respites from the progressive ulceration. Irradiation therapy is ineffective.

VASOSPASTIC ULCERS. Vasospasm is a very rare cause of chronic ulceration. Raynaud's disease is occasionally accompanied by *small* (less than 1 cm. diameter) ulcers of the pads of the finger tips. However, most of the chronic ulcers of the finger tips are manifestations of organic arterial occlusions relatable to cervical ribs, axillary crutch injury ("crutch paralysis"), thrombotic arteriosclerotic, and traumatic blocks of the subclavian, axillary, or brachial arteries, and occlusions of the digital and other arteries of the hand by thromboangiitis obliterans and pneumatic-hammer injuries. In addition, collagen disease (dermatomyositis, periarteritis nodosa, and scleroderma, especially the local form acroscleroderma), is a relatively frequent cause of chronic digital ulcers. All the various types of organic arterial occlusions of the vessels of the arm and hand, as well as the collagen diseases, crutch injuries, Buerger's disease, and pneumatic-hammer injuries, may be associated with blanching or blueing, pain with exposure of the hand to cold, and the reactive cyanotic hyperemia following warming that once was thought to be characteristic only of Raynaud's disease. Obviously, the ascription of a chronic ulcer of the finger pads to Raynaud's disease requires more evidence than the observation of the typical Raynaud's responses to cold and warming. It requires biopsy of a muscle, of the skin of the digit, or of a visible lesion at some distance from the ulcer to rule out collagen disease (especially scleroderma), x-rays of the cervical spine to rule out cervical ribs, and arteriographic examination of the arteries of the arm and hand to rule out the arterial occlusive diseases.

Obviously, the treatment of the chronic ulcer of the finger tips varies with the cause of the ulcer and includes such varied maneuvers as thrombectomy or reconstitution of the flow through or about a localized obstruction of a major artery, the resection of cervical ribs or the anterior scalene muscle, the proper selection of a crutch ("crutch paralysis"), change of occupation (pneumatic-hammer disease), endocrine and other therapy of collagen disease, and *rarely* sympathectomy (Raynaud's disease).

For a time, cervicodorsal sympathectomy was considered to be the appropriate treatment for chronic ulceration of the finger tips when Raynaud's phenomenon could be elicited. However, because under these circumstances sympathectomy has not proved to be an effective means of securing more than a temporary, though at times a prolonged, relief of pain and ulcer, it has been largely abandoned as a primary therapeutic maneuver for digital ulcers associated with Raynaud's phenomenon, excepting for the treatment of the rare chronic ulcer associated with Raynaud's disease itself. However, cervical and upper dorsal sympathectomy is still indicated in the treatment of chronic ulceration of the hand associated with Raynaud's phenomenon, whenever the more specific therapeutic measures fitting the cause of the phenomenon have failed even though, at best, only temporary relief is to be expected from the sympathectomy.

Neurogenic Ulcers. A few chronic ulcers of the finger tips and plantar surfaces of the feet have neurogenic origins (Fig. 8). Syringomyelia, by virtue of the enervation of pain and temperature sensation to the hand, permits repetitive thermal injury to the fingers by cigarettes and burning matches, thereby facilitating the genesis of small, chronic, painless, traumatic ulcers of the skin of the fingers. The proper neurologic examination makes the diagnosis.

Diabetic neuropathy, which early affects loss of pain (pin-prick and inflammatory) and temperature discrimination of the toes and plantar surface of the foot, is often as-



Fig. 9. Squamous cell carcinoma (Marjolin ulcer) of the thigh and buttock. The patient had an old ulcer produced by a burn 13 years previously, which failed to heal. The hyperplastic changes at the edge of the ulcer were of recent origin, however. (Courtesy Dr. J. W. Gale.)

Decubital Ulcers. Any poorly nourished patient suffering from such a prolonged and debilitating illness as chronic intestinal obstruction or tuberculosis may develop decubital ulcers or bed sores, unless the malnutrition is corrected and adequate nursing care is exercised in turning the patient and protecting bony prominences. Local circulatory impairment, due to pressure, plays an important role in the etiology of the decubital ulcers. The skin over the sacrum, iliac crest, trochanter, external malleolus, and heel is especially susceptible on account of the continuous pressure sustained at these points against the underlying bone (Fig. 10). Patients with nerve lesions (spinal cord injury, tabes, and the like) are more susceptible to decubital ulcers than others. The skin becomes slightly reddened, a blister forms, and shortly thereafter the tissue becomes indurated and the skin acquires a cyanotic tint. By this time, however, it is too late to prevent the formation of the ulcer. The process of separation of necrotic tissue from living tissue may extend over a surprisingly long period of time (two to four weeks) and when completed may reveal an enormous destruction of tissue, sometimes exposing the bone. Repair and filling in with granulation tissue is even a slower process. *Occasionally, in neglected cases, an in*fection spreads into the adjacent tissue. The added burden of the infection on an old or debilitated patient may be sufficient to cause his death. The development of decubital ulcers is a reflection on the physician and, to a lesser extent, on the nursing care. If proper attention is paid to the patient's nutrition by maintaining a good food intake with a sufficient protein content and adequate nursing care, i.e., frequent turning and light massage, they will be uncommon. Such treatment is likewise important in therapy of the ulcer, once it has developed. Attention should be directed to cleanliness, bland dressings, and elimination of pressure over the ulcer; healing, however, is slow and requires weeks. Successful closure of the defect by plastic procedures including skin graft (e.g., sliding pedicle graft) can be accomplished after at least partial correction of the nutritional deficits.

Ulcers Due to Radium and X-ray. Shortly after the introduction of radium and x-ray in the treatment of malignant tumors, ulcerations resulting from excessive radiation were commonly encountered. Fortunately, how-

TABLE 4. Rare Vascular Ulcers

Name	Pathogenesis, Predominant Location of the Ulcer, and its Characteristics	Diagnosis	Treatment	Reference
Hypertensive ischemic ulcers	Local cutaneous arteriolar occlusions. Lateral and posterolateral surfaces of the leg. Covered by an avascular membrane with an ischemic border	Biopsy	Cleanliness. Antibiotics. Bed rest until healing begins. Thin split-thickness skin grafting	Hines, E. A., Jr., and Farber, E. M. Proc. Central Soc. Clin. Research, 19:15–16, 1946
Chronic pernio ("erythrocyanosis," "lupus pernio," "chronic chilblains")	Exposure to cold. Located about the ankle and around the leg, predominantly in young women. Spotty erythema, blister, ulcer with a purple base	Biopsy to rule out erythema induratum (no tubercles)	Fever therapy (typhoid vaccine) for active ulceration. Keep out of the cold	McGovern, T., and Wright, I. S. Am. Heart J., 22:583–605, 1941
Erythema induratum	Cutaneous and subcutaneous nodules which break down and become chronic ulcers of the mid leg (calf and shin) of middle-aged women and men. Disease resembles chronic pernio	Biopsy—cutaneous tubercles (no tubercle bacilli in the lesion)	Systemic antituberculous therapy. Excision and skin grafting for the nonhealing chronic ulcer	Montgomery, H. O'Leary, P. A., and Barker, N. W. J.A.M.A., 128:335–341, 1945
Livedo reticularis	Diffuse cutaneous arteriolar obstructions. Reticular (netlike) lividness of the feet and legs (occasionally hands and arms), chronic ulceration about the ankles	Appearance of the extremity	Sympathectomy and avoidance of cold and fatigue	Williams, C. M., and Goodman, H. J.A.M.A., 85:955–958, 1925
Ergotism	Distal arterial thrombosis. Gangrene of tips of toes and rarely of fingers followed by slough of the gangrenous skin leaving a slowly healing ulcer (History of taking ergot preparations for migraine or abortion or abnormal menstrual bleeding)	History	Removal of the drug. Local amputation if spontaneous healing does not occur	
Frostbite	Distal arterial occlusions. Hemorrhagic blisters overlying dead skin which sloughs leaving an ulcer that heals rapidly if small	History and appearance of the acute lesion	Split-thickness skin grafts directly upon granulation tissue	
Traumatic arteriovenous fistula	Ulcer of the stasis type. Penetrating injury to leg or arm Followed by swelling and warmth of the leg and the growth of varices	Auscultation over arteries of the affected member, angiography	Repair of the fistula	

because idiopathic cryoglobulinemia is rare and the secondary form is not. There is no specific treatment for the cryoglobulinemic ulcer. Skin grafts take readily on the clean, granulating base of the ulcer. Other rare vascular ulcers are listed in Table 4.

Neoplastic Ulcers. Practically all malignant neoplasms located in and immediately beneath the skin, whether primary (squamous cell carcinoma, basal cell carcinoma, sweat gland cancers, melanomas) or metastatic, will break down at times, producing chronic, progressively enlarging ulcers.

Marjolin's ulcer is a peculiarly slowly growing carcinoma of the skin, having a scar as its locus. Burn scars constitute its most common site of origin (Fig. 9).

Biopsy, of course, is requisite for the diagnosis of a neoplastic ulcer. The treatment of a neoplastic ulcer is ablation of the primary lesion and its regional lymphatic drainage if nodal enlargement exists.

of gangrene, owing to the lack of muscle in such structures as the phalanges and skin and the interference with voluntary muscular contractility attendant upon pain that is associated with such nongangrenous processes as thrombophlebitis, ruptured tendons and ligaments, and fractures. In other words, the loss of all modalities of cutaneous sensation is the most dependable manifestation of early gangrene.

All gangrenous processes are associated with some discomfort or pain. The severity varies a great deal, being scarcely noticeable by the diabetic neuropath with a gangrenous foot, and being excruciating with clostridial cellulitis and myositis and with acute occlusions of the abdominal aorta (saddle emboli).

All forms of gangrene, infected or not, are accompanied by the general signs of tissue death—namely, fever, leukocytosis, and illness. *Dry gangrene* occurs when the death of tissue is due to arterial obstruction without an associated venous obstruction or infection. *Moist gangrene* develops if the gangrenous process begins when the tissue is edematous and filled with fluid, or in the presence of infection or venous obstruction. Gangrene primarily affects the extremities, being much more common in the lower than upper. Often, indeed, amputation is necessary to save the patient's life. The details of amputations will be found in Chapter 18. Silbert and Haimowici (6) have aptly summarized the needs for amputation in ischemic gangrene to be dependent upon "the extent of gangrene or ulceration, degree of infection, condition of adjacent areas, degree of arterial impairment, and severity of pain." Conservative amputations are being advocated more and more because antibiotics are making them safer.

Arteriosclerotic Gangrene (Senile Gangrene). When gangrene results from arterial obstruction due to arteriosclerosis obliterans it is practically always of the dry type. It is relatively common and occurs in the aged as a result of narrowing of the lumen by the sclerotic process and may or may not be associated with an accompanying thrombosis of the artery. The development of gangrene is usually preceded by a history of pain in the extremity which is, in most instances, located in the calf of the leg. This pain may have been present for years, is dependent upon a decreased blood supply, and is most easily precipitated by extended exercise of the extremity such as walking (*intermittent claudication*). The feet become cold very readily and a feeling of numbness is usually complained of. The actual gangrenous process may occur spontaneously or be started by a slight injury which precipitates inflammation, thereby aggravating the effects of the vascular occlusion. Several toes or the entire foot may be included in the process. Before the line of demarcation forms, a moderate amount of burning pain is complained of. It is frequently relieved by elevation of the foot, especially after the line of demarcation is formed. There is usually a definite sequence of events as far as color reaction is concerned in the development of the gangrene. The tissue first becomes pale and white, and after varying periods of time turns red, later cyanotic, and finally black.

Examination reveals the dried, shriveled, and mummified characteristics of dry gangrene with a hyperemic zone intervening between it and normal appearing skin. Elevation of the foot causes a blanching of the hyperemic areas regardless of whether or not a gangrene is present. There will be no pulsation of the arteries below the obstruction. At times, the entire artery from the femoral on down is involved so that even the pulsation of the femoral artery in the groin may be decreased or even absent. A roentgenogram will reveal calcification along the course of the artery, a finding, however, which is often noted in arteriosclerotic patients without circulatory disturbance. Fever is absent except on the occasions when the gangrenous area is extensive or associated with an infection. Since the gangrene is usually dry, the offensive odor of putrefaction is absent. The line of demarcation will usually not form until the gangrenous process has been present for ten to fourteen days. At first there is no break in the continuity of the skin, but a crack soon appears, deepens, and if the patient refuses operative treatment and survives, will result in a spontaneous amputation.

TREATMENT. In general, the treatment of arteriosclerotic gangrene is amputation, at a level far above the line of demarcation, in tissue whose blood supply is not appreciably diminished (Fig. 11). A more conservative

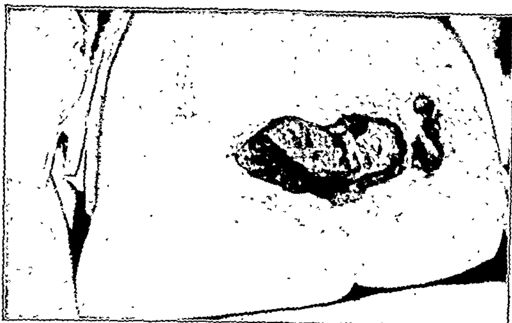


Fig. 10. Decubital ulcer. This ulcer is in the sacral region of a patient with paralysis and anesthesia due to spinal cord injury and was produced by the pressure of a plaster cast applied for fixation of the fractured spine. Healing was eventually complete.

ever, because of a better understanding of dosage and other factors, these ulcers are decreasing in number. The first evidence of injury is a hyperemia of the skin, which is the seat of most of the damage, because of the greater dose of radiation it receives, but more especially because of the sensitiveness of the skin to the rays. The ulceration does not occur for some time after the burn (one to four weeks) and is, in reality, preceded by gangrene. The base is usually smooth and red. The skin surrounding the ulcer is hyperemic and pigmented. Considerable pain may be present. Healing takes place unusually slowly and the ulcer may be unchanged for years. Excision of the ulcer with application of a skin graft may result in a cure. Occasionally a squamous cell carcinoma develops at the site of such a burn. This type of carcinoma is usually not very rapidly invasive and responds satisfactorily to thorough excision.

GANGRENE

The recognition of gangrene is simple after the skin turns black and the member exudes a fetid charnel odor. However, when these signs appear nothing can be done to save the part. Consequently, early recognition of impending gangrene and determination of its cause, while something might be done to limit or reverse the process, are very important. The cardinal signs of impending or early gangrene are: 1. total peripheral sensory denervation manifested by numbness, and total hypesthesia or anesthesia; 2. poikilothermism; and 3. muscular weakness or paralysis. Of these three the neurologic signs are the most dependable, provided that the examination is conducted carefully and intelligently, and such injury as transection of the spinal cord or large nerves does not exist. For instance, diabetic neuropathy without gangrene often is associated with hypohidrosis, anesthesia to pin prick, lack of temperature sense, lack of vibratory sense, and absence of tendon jerks in the foot and lower leg. However, tactile sense and muscle power are not lost with diabetic neuropathy while they are lost early with gangrene.

Poikilothermism is often misleading; with ambient temperatures below 26° C. it often attends acute thrombophlebitis, emotional disturbances, and arterial surgery when there is no danger of gangrene. And when the ambient temperature is above 34° C., the skin of the early anhidrotic gangrenous toe, foot, or leg may feel warmer than the evaporatively cooled, normal sweating extremity.

The assessment of muscle contractility is also often of little use in the early detection

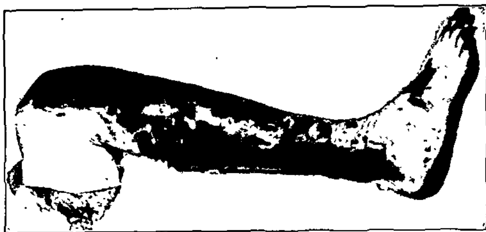


Fig. 12. Gangrene of foot and leg resulting from embolus to the femoral artery, in a young man, aged 26, with rheumatic heart disease.

the vessel wall caused presumably by thrombosis with subsequent canalization or by a primary thickening of the wall of the blood vessel from an inflammatory reaction of some kind. The feet are involved more often than the hands, but there is a tendency toward chronicity with involvement of first one extremity then another. Ulcers of the toes are commonly present and are associated with redness, cyanosis, and mild edema. The disease is described in detail in Chapter 25.

Gangrene Due to Embolism and Thrombosis. The gangrene produced by an embolus is often spectacular because of the suddenness and severity of the initial symptoms. The size of the clot is, no doubt, in most instances increased by an associated thrombosis extending back to the first major branch. The production of the embolus is dependent upon the presence of a primary site, i.e., endocarditis (Fig. 12), pneumonia, typhoid fever, septicemia, and so forth. The embolus may arise from a heart valve, the wall of the heart, the auricular appendage, or the lung. Obviously, superficial gangrene will be produced only when the embolus lodges in one of the four extremities; the legs are more commonly involved than the arms. Frequently the patient is not aware of the primary lesion responsible for the embolus. The femoral artery is the most common site of embolism; next in order of frequency is the common iliac artery, the brachial artery, the aorta, and the popliteal artery (Pearse). Gangrene of both lower extremities may occur when the aorta is occluded, except when a partial obstruction of the distal portion of the abdominal aorta has been produced by such a lesion as an aneurysm, for a period sufficiently long to allow collaterals to develop. The incidence of gangrene following ligation of smaller vessels is approximately as follows: common iliac (45 per cent), popliteal (15 per cent), common femoral (15 per cent), and femoral below profunda (8 per cent). Gangrene is relatively uncommon (somewhat less than 10 per cent) when the major arteries of the upper extremity are occluded, occurring with about equal frequency in obstruction of the axillary and subclavian arteries, but is decreased to near zero when ligation is done between the thyrocervical trunk and the circumflex humeri arteries. In general, gangrene is much more frequent in embolism of the lower than in the upper extremities.

The first symptom experienced is usually a sudden severe pain in the extremity (commonly the calf of the leg), associated with a complete disability including paralysis. The foot becomes white and cold and the muscles spastic. If the embolus has lodged at the bifurcation of the aorta, both legs will usually be involved. After several hours the white, pallid color changes to a cyanotic blush and, after 24 to 48 hours, gangrenous patches will develop.

If the patient is seen within a few hours after the embolus has lodged in the artery, the clot should be removed (embolectomy). If this is done early and completely, gangrene



Fig. 11. Arteriosclerotic gangrene. Amputation was advised, but the patient, a woman aged 67 years, refused and left the hospital.

attitude may be adopted in certain circumstances; for example, when gangrene is limited to one or two toes and popliteal pulsation is still present, a transmetatarsal amputation may be sufficient (McKittrick 7). However, if at any time during hospitalization the *gangrenous process should spread upward or* to other toes, a high amputation in the lower third of the thigh (or rarely in the upper third of the leg) should be performed without further delay. The choice of level for amputation is determined by various tests, including the histamine flare test, as described in Chapter 18. *As already stated, an amputation is not* urgent while the gangrene is of the dry type, but if infection develops, giving rise to the so-called wet type of gangrene, immediate amputation will be indicated. During the preoperative period the foot is protected with a cradle without electric bulbs, since heat is *detrimental* because of increased oxidation in the tissue and other causes, as demonstrated in the experimental work of Brooks and Duncan (8). Strict aseptic care, using sterile towels to protect the involved area against contamination *from such nonsterile objects as* bed clothing, must be exercised at all times.

When amputation is performed in the presence of an infection, it is usually advisable to leave the stump wide open, resorting to reamputation at a later date when the stump is healed or the infection under control. Such serious complications as tetanus, gas bacillus infection, and septicemia are very apt to develop in patients with moist gangrene, particularly following amputation. To combat *these possibilities, it is, therefore, advisable* to use chemotherapy.

Diabetic Gangrene. This type of gangrene is similar to arteriosclerotic gangrene insofar as arteriosclerosis is frequent in diabetics and is the major factor in production of the lesion. However, diabetic gangrene is much more *serious because of the higher incidence* of infection which a diabetic patient is less able to withstand. Once gangrene of a significant degree develops in a diabetic patient, amputation is practically always indicated; delay is rarely *justifiable except for the preoperative* correction of acetonuria. It should be emphasized, however, that uncomplicated infections (as occur most commonly in the foot) can be treated by incision and drainage as in nondiabetic patients. Of recent years amputations are becoming less radical (7). More details *of diabetic gangrene will be found in* Chapter 19.

Thromboangiitis Obliterans (Buerger's Disease). The obstruction in thromboangiitis obliterans is apparently due to a thickening of



Fig. 13. Traumatic gangrene of hand, 22 hours after injury. Note the crushed and lacerated tissues of the forearm; a severely comminuted fracture of the radius and ulna was also present. Amputation necessary because of the rapid progression of the gangrene. (St. Louis City Hospital.)

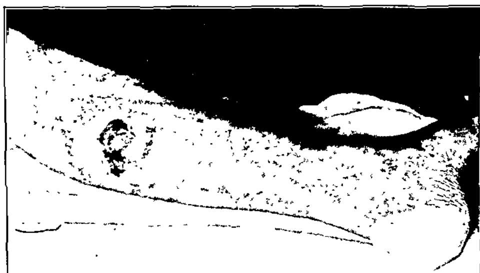


Fig. 14. Hemolytic streptococcus gangrene of Meleney. Onset four days previously, in a healthy man 26 years of age, with swelling of leg, fever, and other systemic manifestation of infection. This is an unusually mild case and subsided spontaneously.

lesion responds well to antibiotics, particularly to heavy doses of penicillin.

Meleney has also described a *synergistic* or *symbiotic type* of bacterial gangrene which on culture yields in most instances a hemolytic *Staphylococcus aureus* and a microaerophilic nonhemolytic *streptococcus*. Because of its tendency to spread, it is often called a phagedenic ulcer. This lesion differs sharply from the one described above in many respects. *It is apt to be a single lesion and* commonly develops about the tenth postoperative day at the site of a stay suture following an abdominal operation. The lesion at first resembles a carbuncle with a wide area of inflammatory tissue and, in reality, produces gangrene of the skin, because of the undermining characteristics of the infection. *The destructive effect is usually superficial* and confined to the subcutaneous tissue immediately under the skin, but spreads rapidly in all directions. As the infection progresses, the skin becomes a bright pink in color for a distance of 1 to 3 cm. from the edge of the ulcer, but after two or three days the margin of this pink area becomes raised, cyanotic, and finally becomes necrotic, leaving an ulcerating base. The edges are extremely

will be prevented. The position of the embolus will be much higher than the external signs, but accurate localization is sometimes difficult, often requiring arteriography. It is usually preferable to open the artery over the upper limits of the clot, which is removed by suction and gentle traction. If the patient is seen after the late signs of gangrene are manifested, embolectomy will be of no value and it will be preferable to wait for the development of a line of demarcation between the gangrenous and viable tissue before performing amputation. Rarely is embolectomy indicated if more than 48 hours have elapsed since the embolism.

Regardless of whether or not embolectomy is performed, certain routine procedures are advisable. The use of vasodilating drugs such as papaverine (0.5 grain) or sodium nitrite (1 grain) is advisable. The extremity (e.g., foot) is protected by a cradle, but no external heat should be applied since heat accelerates oxygen consumption in the affected extremity. The extremity should be kept in a slightly dependent position—not elevated. Regardless of whether or not embolectomy has been performed, the patient should be heparinized immediately and a delayed clotting time maintained for several days (Chapter 25).

Traumatic Gangrene. Because of the increasing number of industrial and automobile accidents, it is becoming necessary that traumatic gangrene be given more consideration than previously, especially when we consider that many amputations performed at the present time for crushed or injured extremities are in reality not necessary. Before the aseptic era, amputations for such injuries were indicated to prevent the universal development of serious infection. Such infection can, at the present time, be largely prevented by proper treatment of the wound (Ch. 13). Although a limb may be severely damaged, it is certainly worthwhile, with a very few exceptions, to postpone amputation with the hope that a sufficient blood supply will develop from the unsevered tissue to prevent gangrene. This is especially true if the bones of the extremity are not fractured. Often it will be discovered that the gangrene will be limited to the toes or fingers and that the important structures, such as the joints, can be preserved. It may require several weeks for collateral circulation to develop to the point where healing will progress, but if a portion of the hand or foot can be saved (even if it is partly disabled), it is usually of more value to the patient than an artificial limb. One of the strongest arguments for conservative treatment is that amputation may be safely performed at a later date, if it becomes evident that the extremity distal to the injury cannot survive. If the patient is watched carefully, only on rare occasions indeed will this delay jeopardize the patient's life, particularly since antibiotics are available for the control of infection. However, if considerable tissue (particularly muscle) is distinctly not viable (Fig. 13), it will be a dangerous focus for the development of gas gangrene. Débridement and primary repair of partially severed extremities should be done with as little manipulation as possible to prevent injury to what blood supply is remaining. It is surprising how often huge amounts of soft tissue which are attached to the body by mere shreds will survive, especially if the patient is received immediately after the accident and the wound properly treated. Frequently, sympathetic block with Novocain, repeated at intervals of a day or two, will be effective in decreasing spasm and increasing blood supply. The massive injuries of war are discussed in Chapter 42.

Bacterial Gangrene. Perhaps the most serious type of gangrene is that produced by a number of gas-producing anaerobic organisms, among which the *Cl. perfringens* (*B. welchii*), *Cl. oedematiens*, and *Cl. septicum* are the most important. It was an extremely common affliction during World War I, but is encountered only occasionally in civil life. For detailed description see Chapter 7.

In 1924, Meleney described a particularly serious type of gangrene caused by the *hemolytic streptococcus*, which is definitely characteristic, and can readily be differentiated from the others. It is now relatively uncommon. The initial lesion may or may not be associated with trauma. The skin over a large area becomes red, slightly swollen, and hot. A moderate amount of pain and tenderness are present. After 24 to 48 hours this area of redness becomes cyanotic, and blisters form on the surface. A short time later the skin becomes definitely gangrenous and separation from the viable tissue begins (Fig. 14). The



Fig. 16. Gangrene due to freezing. A, four days after freezing; B, five days later. Note that definite demarcation is beginning to show up on the left foot. Patient contracted tetanus on the fourteenth day and died. (St. Louis City Hospital.)

almost indistinguishable from that caused by the symbiotic growth of the staphylococcus and streptococcus. Amebas may be found in secretions obtained from the depth of the wound, in tissue removed, or by biopsy. The lesion responds well to antiamebic therapy.

In advanced cases of Raynaud's disease the fingers and toes may develop a gangrene which may or may not be associated with considerable pain. The gangrene, however, is always of a superficial type; never is an entire extremity involved. For detailed discussion see page 146.

Noma is a gangrenous process of infectious origin occurring about the mouth and cheeks of debilitated children, but is fortunately becoming quite rare.

Gangrene resulting from the poisonous effects of ingested *ergot* is extremely rare, but may occur in elderly people who have eaten large quantities of rye bread contaminated with the fungus, *Claviceps purpurea.* Young women who have taken large amounts of ergot to promote abortion may also suffer from the disease. The most frequent sites affected are the fingers and toes.

Gangrene resulting from *strangulation* is, of course, observed commonly in the intestine in strangulated hernias. Rarely it occurs in the gallbladder as a result of edema and thrombosis of vessels. Still more rarely is it encountered in extremities following injuries in which a plaster cast has been applied too tightly. Such an event is obviously a serious reflection on the surgeon responsible for the application of the cast.

Gangrene of the lung is a form of pulmonary infection in which several (probably symbiotic) organisms are involved and is accompanied by foul expectoration and fulminating symptoms.

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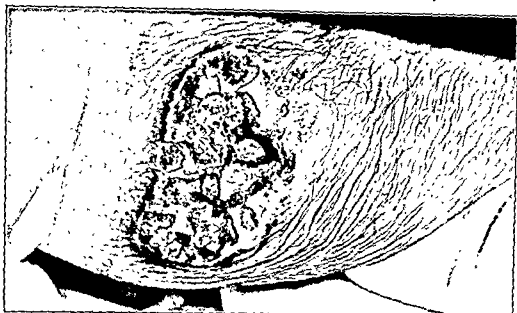


Fig. 15. Bacterial gangrene, symbiotic type (*Meleney*). *Onset six months previously in a woman aged* 30 years. When first seen, the edges of the ulcer were raised, reddened, and very tender; a few patches of gangrenous skin were likewise present. Culture revealed a microaerophilic nonhemolytic streptococcus and a hemolytic staphylococcus. The photograph was taken after seven days' rest *in bed with meticulous* care of the wound. Epithelium is beginning to grow at the edges and likewise in certain areas over the base of *the ulcer. Important* therapeutic procedures are radical excision, local application of zinc per oxide, and the use of penicillin and other antibiotics.

painful, are tender, and often have a tendency to bleed on the lightest touch. The advancing red or pink edge is sharp and serpiginous and leaves healing granulation in its wake which slowly epithelializes (Fig. 15). Antibiotics *and zinc peroxide should* be tried. *If improve*ment is not marked, excision of the gangrenous area and red border should be carried out because it is so effective. Skin grafting is done at a later date.

Thermal Gangrene. Either excessive heat or freezing will produce gangrene. The destruction of tissue in most burns is confined to the skin and subcutaneous tissue, because of the short exposure. On the contrary, the gangrenous process caused by freezing may include the entire digit or extremity if the member is exposed for hours, as is frequently the case (Fig. 16). See Chapter 15 for detailed discussion.

Miscellaneous Types of Gangrene. A *chemical gangrene* may be produced by spilling corrosive *substances* (e.g., strong *acids* and alkalis) on the skin, or by the intentional application of harmful medicinal agents. The most common example of the latter is the repeated and persistent application of "carbolized petrolatum" (containing varying *amounts of phenol) to lesions on the extremi*ties. Since the phenol acts as a local anesthetic, its "soothing" local effect masks the tissue destruction which is only evident 24 to *48 hours later.* The process of *epithelialization* progresses slowly, following chemical burns. This is decisively illustrated by the slough and sluggish ulcer which develops following the accidental perivascular *injections* of sclerosing solutions (*e.g.*, sodium salicylate) for obliteration of varicose veins, or of calcium salts being injected intravenously. If an acid or strong alkali is spilled on the skin *it would appear* advisable theoretically to treat it with an antidote or antagonistic chemical. Practically, it has been found that the use of large amounts of water is more effective, *because* the application of *an* antagonistic chemical may produce as much damage as the offending chemical, thereby more than offsetting the value of chemical *neutralization.*

Amebic gangrene of the skin is rare, but has been reported in a few instances chiefly as a superficial gangrenous process *complicating abdominal* operations. The lesion is

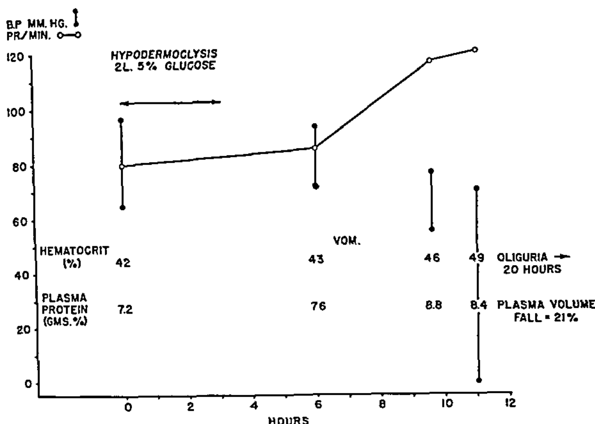


Fig. 1. The hazard of hypodermoclysis with glucose solution. Note the evidence of circulatory impairment and fall of plasma volume following the subcutaneous injection of 2 liters of 5 per cent (isotonic) glucose in a young woman. The changes were due to transfer of water and electrolyte from the blood to the glucose-containing space. Eventually, equilibrium was reached, absorption was completed, and the changes returned to normal. (Courtesy, William E. Abbott.)

sions of the nutritional aspect of surgical therapy may be found in papers or texts by Holden (1), Ravdin (2), Rhoads (3), and Elman (4). Although the problem of therapy is, to a large extent, biochemical, it is readily solved in most cases by relatively simple knowledge of fluid and food requirements in terms of their basic elements. Six primary nutritional substances make up the normal well-balanced diet and, indeed, comprise the essential constituents of body tissue and fluids. They are: 1. water; 2. electrolytes (minerals); 3. carbohydrates; 4. fats; 5. protein; and 6. vitamins. Because fat and carbohydrate can be considered together as supplying calories, five rather than six elements will be discussed below. It may be noted, however, that fat and carbohydrate each serve several extracaloric functions. For example, glucose is important in preventing the acidosis of starvation, especially after operation, but given alone without the required salt can result in actual hypovolemia (Fig. 1).

The basic principle of therapy is the *adequate but not excessive replacement of losses*, both normal and abnormal, by providing an intake of the right kind in adequate amounts, in an appropriate manner, before, during, and after operation or injury. The objective is to restore or maintain normal balance; i.e., to keep the blood and tissues as close as possible to a normal level in as simple a way as possible, and thus to achieve the maximum in rapid and complete convalescence from injury, infection, or operation.

The five nutritional elements or factors enumerated above will be discussed separately, although there is a great dependence of one on the other. For example, water and electrolyte balance may be difficult or impossible to attain unless serious protein deficiencies are also corrected; glucose cannot

9

FLUID, ELECTROLYTE, AND CALORIC BALANCE; SURGICAL METHODS

Fluid Balance
Electrolyte Balance
Therapy of Water and Electrolyte Imbalances
Caloric Needs
Protein Needs
Vitamins
Methods of Fluid and Food Administration
Surgical Methods

In his classic observations on physiology, Claude Bernard emphasized the body's need for maintaining a uniform and optimum *milieu interieur,* or body composition, despite external changes imposed upon the body during health but especially in sickness.

Changes in body fluids and tissues can sometimes be detected by chemical examinations of the blood and urine, by measurement of body spaces (compartments) including blood volume, and by tissue analysis. A more direct and bedside approach is knowledge of the intake and output expressed in terms of *balance.* It is a safe assumption in most cases that the composition of the body tissues and fluids is being maintained at a normal level when the intake and output are equal, or, in balance. Deficits follow *negative balance;* that is, when the loss exceeds the intake. On the other hand, to correct a deficit, replacement of the loss means a temporary *positive balance;* that is, retention until the loss is replaced and normal composition is achieved. On the opposite side of this therapeutic coin are the mistakes made by providing too great an intake, more than is needed or can be excreted, thus causing an abnormal retention, or *positive balance.* A common example of the latter is the so-called *salt edema* which follows the excessive infusion of salt solution in patients who, because of renal impairment, cannot promptly excrete the unneeded excess. However, should the edema be successfully reduced through adequate diuresis, a temporary and therapeutic *negative balance* will ensue. Since mistakes in therapy are still common, it will be necessary in this section to describe the nature and therapy of excessive administration of fluids and foods, and discuss deficits from inadequate administration to replace normal or excessive losses.

In mild illness, as in health, intake of the required amounts of fluid and food to maintain normal balance can usually be left to the patient. Because of anorexia, this is not always true in the seriously ill, surgical or medical patient. Indeed, no intake may be possible because of obstruction or vomiting. Added to this decrease in or complete absence of intake, are the abnormal losses seen in surgical patients which increase the degree of negative balance with its ensuing tissue and fluid deficits. To assure a minimum intake of the food and fluid elements necessary to approach or maintain normal balance becomes, therefore, one of the most important responsibilities of the surgeon in the care of his patients. Without such care, operative risks, postoperative complications, and even mortality increase unnecessarily and convalescence is delayed unduly.

The different elements in the body involved in maintaining normal balance or optimum composition of body fluids and tissues are actually the same as the ailments in a normal well-balanced diet. Thus, one is justified in approaching this field of surgical care from the nutritional point of view. Indeed, the American College of Surgeons has recognized its importance by setting up a permanent Committee on Nutrition. Provocative discus-

ELECTROLYTE BALANCE

Electrolytes include many kinds of salts, of which the most important in the extracellular fluid is sodium chloride. Sodium comprises nearly 100 per cent of the cations and chloride 80 per cent of the anions in the extracellular fluid, the rest of the anions being largely bicarbonate.

Sodium Chloride. The minimum intake of *sodium chloride* required for balance, under basic and normal conditions without disease or abnormal losses, is probably less than 1 gm. per day. Ordinarily, however, about 5 to 8 gm. are normally ingested and excreted; the difference is probably largely a matter of taste, the origin of which has had an interesting history (5). Requirements increase tremendously in order 1. to replace losses of electrolyte-containing fluids occurring in excessive sweating, vomiting, fistula, or diarrhea; 2. to replace the extravasation of extracellular fluid into distended loops of bowel or stomach; or 3. to replace fluid loss accompanying large areas of such inflammation as those produced by burns, thrombophlebitis, insect bites, peritonitis, and pleuritis (Fig. 2).

Salt deficiency alone is also called *water intoxication* when it follows the loss of both water and salt, mentioned above, and water alone is ingested or given. First described by Rowntree in 1922, and many times since, it is still encountered all too frequently. An example is the patient with an extensive burn, after severe diarrhea, between bouts of vomiting, or during excessive sweating, who drinks large quantities of water to slake his thirst. Iatrogenic salt deficiency follows the intravenous infusion of glucose solution alone in patients who have vomited considerably or who have drained large amounts of gastric contents through an indwelling catheter. Excessive water intake alone may lead to the same end result inasmuch as the resulting diuresis provokes a normal salt loss in the urine. This was true in one of the first cases of water intoxication reported (6), in 1938, of a woman who, after hysterectomy, was allowed to absorb huge amounts of tap water per rectum through a continuous proctoclysis. Her life was saved by prompt administration of sodium chloride. Plasma sodium in these cases is unusually low. In water intoxication, mental symptoms dominate and may be associated with convulsions. A mistaken clinical diagnosis of cerebral vascular accident is thus often made, especially in older patients.

Sodium chloride deficiency, when allowed to develop to a serious degree because of excess unappreciated losses, results in mental confusion and finally *shock* with absent radial pulse. It responds miraculously to sodium chloride therapy.

Combined water and electrolyte deficiencies are perhaps the most common and follow unreplaced losses as mentioned above. Clinical manifestations are usually called *dehydration* or *anhydremia,* although strictly speaking these terms should be reserved for water deficiency alone. The signs and symptoms vary considerably, depending upon the severity and duration of the loss, and upon the rapidity with which it has occurred. A deficit of water and salt should always be suspected in any patient in whom there has been a history of water deprivation and low urinary output for several days; particularly when abnormal losses have been inadequately replaced. The dehydrated patient exhibits a general dryness of the body tissues, especially of the tongue and mucous membranes. The eyes and cheeks are often sunken in severe cases, a phenomenon which has been described as "Hippocratic facies." Mental apathy may even lead to coma. Subjectively, the patient first complains of weakness and anorexia and, when water loss is predominant, of extreme thirst. Vomiting itself is not uncommon, even without the ingestion of fluid. When there is a rapid loss of fluid, shock may occur, especially when plasma is also lost as in peritonitis, acute intestinal obstruction, hot water burns, and, occasionally, in extensive cellulitis or inflammatory edema of an entire extremity in thrombophlebitis. The most dramatic picture, after severe persistent losses through vomiting and constant purging, used to be seen in cholera victims, many of whom became comatose, wasted, shriveled, and actually went into shock within a matter of hours or days.

Water and electrolyte excess results from mistakes in therapy during which more sodium chloride solution is injected than is needed or can be excreted by the kidneys. This is commonly true after operation, or

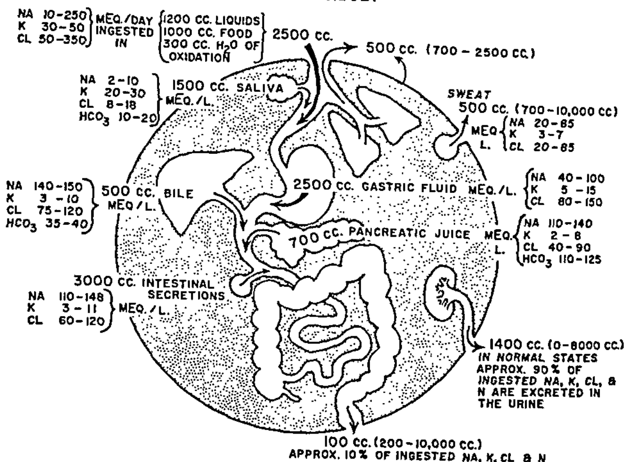


Fig. 2. Normal water and electrolyte exchange. The diagram summarizes the various kinds of fluid exchanges, then amounts and approximate composition under normal conditions. On the right, the arrows indicate the water and electrolyte output due to (*a*) insensible loss through lungs, skin, and as sweat; (*b*) urine; and (*c*) feces. Under normal conditions, balance is achieved because these losses add up to the oral intake. The losses under abnormal conditions are shown in parentheses. (Courtesy, William E. Abbott.)

be metabolized normally without adequate supplies of thiamin; protein utilization is greatly affected by the intake of carbohydrates.

FLUID BALANCE

Water, though the simplest, is also the most essential food element, since without any water intake, even though other elements are supplied, life is impossible for longer than a week or ten days in man. Water comprises 70 per cent of the total weight of a lean, almost fat-free adult. In a 70-kg. man this comes to 50 liters, of which 14 liters represent extracellular fluid (3 liters as plasma, the rest as interstitial fluid). The largest part, or 36 liters, comprises intracellular water. In a normal adult, balance is achieved with an intake of about 2 liters of water per day or 30 ml. per kg.; in the newborn, it approaches 100 ml. per kg. This intake permits the normal kidney to excrete all waste products and to replace the insensible losses without leading to water deficiency (Fig. 2).

Water deficiency alone follows complete deprivation of water since insensible water loss is obligatory and cumulative; added to this is a continued though diminished urinary output. A more severe and rapid water deficiency follows increases in insensible water loss, in fever or high environmental temperature with low humidity, unless, of course, the loss is replaced. The clinical picture, often called dehydration, is that of extreme dryness of the tissues, profound thirst, and mental apathy. Water deficiency in disease is actually more commonly associated with a deficiency of electrolytes and is, therefore, discussed in the next section.

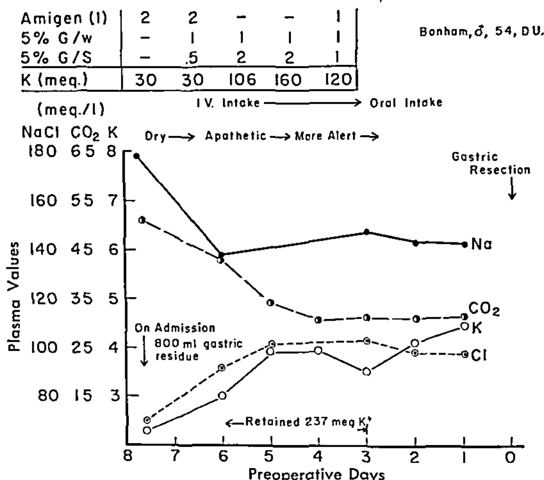


Fig. 3. Potassium deficiency in a patient with pyloric obstruction. The patient was a 54-year-old mechanic with a long history of duodenal ulcer, including periodic pyloric obstruction and loss of weight. After eight days of preparation, adequate gastric resection was carried out, followed by a gastroduodenal anastomosis. Normal oral intake was reached by the sixth and the patient was discharged on the eighth postoperative day. Since then he has remained free of symptoms and has gained 30 pounds in weight.

Note especially in the data above the high plasma sodium and low potassium levels on admission, indicating unreplaced water and potassium loss, and the low chloride and high CO_2 levels (hypochloremic alkalosis), characteristic of loss of acid gastric contents and of potassium deficiency. These biochemical findings could have been predicted since only isotonic sodium chloride had been previously given without water (as glucose and amino acid solution) or potassium. The failure of previous saline therapy alone to correct the potassium and insensible water loss emphasizes the need for attention to all elements in replacement therapy.

The relief of pyloric obstruction before operation indicated that spasm, edema, and gastric atony were largely responsible. Gastric atony can be produced by intracellular potassium deficiency, which, in this case, was corrected by a total intake of 28 grams (440 mEq.) of potassium chloride. Note that only 18 grams (237 mEq.) thereof were retained because of the inability of the kidney to completely conserve K^+ even during a deficiency. Note also that a maximum of 4 grams (53 mEq.) of KCl were added to each liter; higher concentrations may lead to pain and phlebitis.

Preoperative preparation, as illustrated in this case: (*a*) reduces the technical difficulties at operation by reducing edema of the stomach wall and in the pylorus; (*b*) lowers operative mortality by correcting serious biochemical deficiencies, which always increase risk; and (*c*) shortens the period of convalescence by promptly restoring normal gastrointestinal function.

when more simple means prove ineffective, and when there is a fair chance that renal function is not irrevocably lost.

The role of magnesium in electrolyte deficiencies is difficult to evaluate particularly since accurate measurement is difficult. The

when the patient suffers protein deficiency. The usual outcome is edema, often called "salt edema," leading to wound disruption, leakage or obstruction at gastrointestinal anastamoses, and pulmonary edema. Retention of fluid in this way is to be suspected when the urinary output is unusually small following the administration of large amounts of salt solution. Once edema develops, it is difficult to relieve. Prevention is thus far better than cure.

Potassium. Knowledge of the clinical importance of potassium has greatly increased within the past decade, thanks to the development and wide use of modern flame photometry (7), with which the plasma and urinary potassium can be accurately and rapidly measured in any good clinical laboratory. *Since the whole body potassium is almost entirely intracellular, the plasma level is quite low, i.e., only 4 to 5 mEq. per liter, in contrast to a value of 140 mEq. for sodium.* Nevertheless, low levels, down to about 1 mEq. per liter, have been found in potassium deficiencies, and high values, above 7 mEq. per liter, in certain cases of renal insufficiency. Plasma levels, it should be emphasized, do not necessarily reflect intracellular levels which often are of much greater importance (see below).

Perhaps the most common condition leading to *potassium deficiency* is that which follows correction of water and salt deficits with *saline solution alone, when electrolytes are being lost by gastric decompression* (Fig. 3) *or some similar mechanism.* What happens is that, with the restoration of the urinary output, large amounts of potassium are lost in the urine due to the relative inability of the kidneys to conserve potassium. Another type is the hypokalemia (hypopotassemia) associated with persistent postoperative hypochloremic alkalosis uninfluenced by an increased salt intake (8). The mechanism is not entirely clear, but the blood chemical changes and clinical manifestations can be corrected readily by the administration of potassium. Recognition of potassium disturbances is often hampered by the need for distinguishing between intracellular and extracellular deficits. The latter can be detected by finding a low plasma level. The former can be determined only by measuring intake and output of fluid, and finding that potassium administration leads to a positive balance, thus indicating the therapeutic retention of this salt (9). *Another disturbance which requires further study is the loss of intracellular potassium, with its replacement by sodium, owing to altered cellular permeability or actual cell damage, often associated with the effect of adrenocortical steroids.*

Potassium deficiency produces a variety of clinical manifestations depending upon the severity and rapidity of the loss. Mental apathy, even disorientation, is frequently seen. There is muscular weakness and gastrointestinal paralysis often simulating intestinal obstruction or paralytic ileus. Potassium deficiency can often be prevented by including a small amount of potassium in the intravenous fluids. Correction of potassium deficiency is often difficult, particularly when the parenteral route alone must be used, *because potassium chloride is irritating to the vein in concentrations above 4 gm. per liter.* Since total deficits up to 75 gm. or more of KCl may occur, and since but half the infused salt may be retained, a week or more is often required to correct a severe deficiency. Concentrated solutions of KCl, made to supplement other solutions, must never be injected, as such, into a vein because of the danger of cardiac arrest.

Increased potassium levels are associated with renal insufficiency, and may be *high enough to produce signs of potassium intoxication* which are similar to those of uremia. The electrocardiogram is much more valuable in the diagnosis of high potassium plasma levels than it is for low potassium plasma levels. Therapy is that for renal insufficiency. Also of value is the slow infusion of 25 per cent glucose (with increase of glycogenesis) and of sodium bicarbonate (alkalosis increases and acidosis decreases the *movement of potassium from the plasma to the cell).* *Administration of cation exchange resins* when properly given, even per rectum, has proved a simple and often an effective way of reducing a high potassium plasma level. The artificial kidney has been widely used and will undoubtedly and effectively lower the high plasma level of potassium and urea with obvious clinical benefit. *Its practical application is not easy and should, therefore, be used only*

CALORIC NEEDS

Calories are next in importance to water. In the normal diet, calories are provided by the intake of carbohydrate and fat, whereas during caloric deprivation the energy needs are supplied by the breakdown of fat and muscle tissue, because there is no significant storage of carbohydrate in the body. The depletion of adipose tissue is, of course, physiologic, particularly when fat is present in large amounts. On the contrary, the loss of protein tissue is undesirable (see below).

For a normal adult at rest in bed, caloric balance with no loss of body tissue can be met with a basal intake of 1,500 to 2,000 calories, or, about 25 calories per kilogram of body weight. In infancy, the comparable figure is 60 calories per kilogram of body weight. These needs are increased in fever. In most surgical patients immediately after operation, it is difficult or impossible to maintain such a high intake, particularly when only the parenteral route is available. Some limitation in the total intake is, therefore, temporarily necessary in most cases. Since 80 to 90 per cent of the bulk of the normal diet consists of carbohydrate and fat, one is justified in temporarily reducing the total intake thereof rather than that of protein, which indeed occupies but a small portion of the bulk of the normal diet. The reasons for this are many; the main one is that the inclusion of protein even in the subcaloric intake reduces the degree of tissue protein depletion as compared with a protein-free intake. When full caloric intake cannot be achieved it is far better to ensure an intake of about 1,000 calories and to include an adequate amount of protein rather than to leave the intake to chance or limit it entirely to carbohydrates. In the case of patients able to drink but not chew, a liquid intake can readily be provided. The same principles apply when the parenteral channel is indicated. About 800 calories are the maximum that can be given in 2 liters of 10 per cent intravenous glucose. Ethyl alcohol may be added as a source of more calories (16), but the side effects seem to preclude its use as routine. Emulsified fat is utilized when given intravenously and will aid in solving the problem of adequate parenteral caloric needs. A new product which is comparatively free from reactions (17) may meet this urgent need. Fructose rather than glucose has certain advantages, especially in reducing the loss of sugar in the urine and in avoiding postinfusion hypoglycemia (18, 19). In severe malnutrition it will be necessary to increase the caloric intake to several thousand per day to achieve satisfactory nutritional rehabilitation.

PROTEIN NEEDS

Protein needs are so much more important to the surgical patient than carbohydrate and fat as described briefly above, that protein metabolism will be discussed in detail under a separate heading. Acute protein losses, such as sustained in hemorrhage and acute inflammation (e.g., burns, peritonitis), can usually be met by transfusion of blood or plasma as discussed later. More chronic protein deficiencies are due to persistent negative protein (often called nitrogen) balance and are frequent especially in surgical patients. Under normal conditions, protein balance can be achieved with an intake of about 1 gm. per kilogram or about 70 gm. per day. However, an increased tissue protein breakdown known as the "catabolic phase of injury," may lead to the wastage of as much as 250 gm. of tissue protein a day, or three times the normal intake. It is obvious that increasing protein deficits will follow such large losses unless they are adequately replaced. Nevertheless, because surgical patients immediately after operation usualy have severe anorexia, protein intake falls to zero so that protein deprivation is added as another factor leading to an increasing degree of negative balance.

Protein deficiency should always be suspected in any patient with inadequate intake, particularly in the presence of excessive protein losses. Blood chemical measurements may reveal such a deficit in the form of a low plasma protein concentration, called hypoproteinemia. The most important plasma protein fraction in such cases is albumin, which can also be readily measured. Hypoalbuminemia may also be due to actual loss, as in hemorrhage, burns, or extravasation of various kinds; also, to deficient formation of pro-

blood level is too low for the application of flame photometry. A recent study of deficits in man has been reported by Fink (11).

THERAPY OF WATER AND ELECTROLYTE IMBALANCES

In order to prevent deficiencies and to avoid excessive intake, one may start with the routine needs for water and electrolytes in a normal adult maintained on parenteral fluids after operation. In such a case, about 2 liters of water per day are probably sufficient. Of this, 1 liter will be needed for urinary excretion and 1 liter for insensible losses and any small amount of abnormal loss. The electrolyte intake should include sodium, potassium, chloride, and phosphate. Such a mixture was used in a series of cases (12) and shown to meet the daily maintenance needs of the average postoperative patient without leading to excessive retention. As mentioned later, the intake should also include carbohydrate and, preferably, amino acid mixtures.

The therapy of existing deficiencies depends primarily upon the history and clinical manifestations. Measurements of the serum sodium, chloride, and bicarbonate levels and of urinary chlorides are also helpful as a guide to therapy, but are not absolutely essential and may be misleading. In pure water deficiency, several liters of water plus a few grams of sodium chloride are all that are required. Parenteral infusion, when indicated, should contain largely glucose and amino acids and should be continued until diuresis is established. Many such solutions are available containing necessary but minimum amounts of the electrolytes mentioned above. In combined water and salt deficiency, isotonic saline or, preferably, physiologic saline is indicated. Some colloid, either blood, plasma, or a substitute, should be added whenever the loss occurs into the tissues, as in inflammatory edema, and particularly when shock is present. When the loss occurs into the tissues, control of shock is the primary indication for therapy. Reabsorption and excretion of the fluid by the kidney will occur sooner or later. Not only must excessive infusion be meticulously avoided but the amount and rate of infusion should be reduced to the minimum needed to maintain the circulation. In salt deficiency (water intoxication), isotonic saline may be effective, but hypertonic salt, up to 5 per cent in doses of 200 ml. for an adult, is preferable, especially when edema is present. In "salt edema" a pure water intake aided, perhaps, by a mercurial diuretic may be effective. Hypoalbuminemia or anemia should also be corrected simultaneously.

The reader is referred to a number of excellent texts in which the various types of water and electrolyte deficiencies are discussed in great detail (13, 14, 15). For purposes of simplification, three of the more common types of water and electrolyte deficiencies are briefly described in Table 1.

TABLE 1. Commoner Types of Water and Electrolyte Disturbances

NAME	PATHOGENESIS	MECHANISM	EXAMPLES	THERAPY
1. Water deficiency (dehydration)	No replacement of normal (or excessive) cumulative insensible water loss	Thirsting, hot, dry environment, fever	Esophageal or pharyngeal obstruction, "life-raft victims"	Large water, little salt* intake
2. Water and salt deficiency (dehydration)	No replacement of abnormal losses of fluid containing electrolyte	Vomiting, diarrhea, excessive sweating from fever, or hot, humid environment, inflammitory extravasation	Pyloric obstruction, intestinal obstruction or fistula, ulcerative colitis, hot-water burns	Large water and salt* intake
3. Salt deficiency (water intoxication)	Excessive water intake with normal or excessive salt loss	Same as above, plus pure water replacement	Infusion of glucose solution, or drinking pure water after water and salt losses	Large salt* and little water intake

* Salt refers to sodium chloride preferably with added bicarbonate or lactate.

sues. This process, however, is inefficient, expensive, and slow.

Protein intake is probably undesirable during the acute phase of renal impairment because it increases the degree of nitrogen retention in the blood and tissues. A protein-free (and limited water) intake is therefore indicated. In severe hepatic insufficiency, the oral protein intake should be kept at a moderate level because the digestion and absorption of large amounts of protein (which occurs inadvertently in severe intraintestinal hemorrhage) may be harmful by increasing the blood ammonia level, which seems in some cases to induce or aggravate existing hepatic disease, even to the point of coma.

VITAMINS

Vitamins are, of course, an essential part of the dietary intake and are indicated in all surgical as well as other patients. It is difficult or impossible to measure vitamin balance. Moreover, vitamin deficiencies are seldom seen clinically even in the malnourished patient. The need for many vitamins (25), however, especially vitamin C, is apparently greatly increased after injury. Since excessive intake of most vitamins is apparently harmless, there is usually no particular problem in providing a large and adequate vitamin intake. A small pill by mouth or a small ampule by injection supplies the daily requirements. Pure mixtures of the most important vitamins are now available and, actually, are seldom missing from the intake of all patients, whether their food is taken by mouth or by infusion.

METHODS OF FLUID AND FOOD ADMINISTRATION

Although it is possible in most cases to provide an adequate intake by the oral route, the parenteral channel is sometimes indicated. Each will be discussed separately. Transfusion may be needed in either case.

Oral Administration. The oral route should be used whenever possible. In the face of severe anorexia, however, special attention on the part of the surgeon, and sometimes individualized nursing care, may solve the problem of assuring an adequate intake. Occasionally persuasion is effective. Hypnosis has even been used with apparent success (26). If the patient will take liquids but refuses to chew solid foods, a palatable drink can readily be provided which contains each of the essential nutritional elements, as already discussed above. The help of a good dietitian is often invaluable. In order to restore the severely malnourished as well as to provide a minimum intake for the acutely ill, the initial caloric intake should be low to avoid vomiting, distension, and diarrhea, but should be increased as rapidly as possible. In many cases a high fat intake, in spite of its caloric superiority, is not recommended because it slows the emptying of the stomach and tends to decrease appetite.

Tube feeding may be necessary to assure an adequate intake if the patient is unconscious or is unable or unwilling to swallow a full liquid diet. Many former difficulties with tube feeding have been solved so that this method is now simple and safe, thanks to the use of a small-gauge plastic tubing which is nonirritating and scarcely noticed by the patient. However, it requires a feeding formula which does not block the narrow lumen of the tube. A widely used, finely divided powder suspended in water has proved quite satisfactory (27). A gastrostomy similarly permits fluid and food intakes in patients with esophageal obstruction. A jejunostomy, when the obstruction is beyond the stomach, does the same.

Only simple fluids such as water and saline solution can be given effectively by rectum (proctoclysis). Popular decades ago, proctoclysis is seldom used at present. One difficulty is rectal irritation, which soon leads to expulsion of the solution. The rectal route is often utilized in patients who cannot take anything by mouth for the administration of such drugs as paraldehyde, chloral hydrate, dilaudid suppositories, and many others.

Parenteral Administration. This method for the provision of fluid and food intake ranks with other great advances in surgery in that it has extended the frontiers of disease now amenable to operation. By aiding in preoperative preparation, it has gradually reduced risk; by preventing or correcting acute deficits during and after operation, it has minimized complications, lowered mortality, and shortened convalescence.

tein, as in liver disease, as well as to protein starvation itself. Hypoalbuminemia, when severe, will lead to nutritional edema; i.e., edema which is not cardiac or nephritic, but which follows the lowered colloidal osmotic pressure of the plasma resulting from fall in the level of plasma albumin. Other such factors as gravity, venous pressure, exercise, tissue tension, or the intake of unneeded salt, are also important in precipitating nutritional edema. Nutritional edema is of great importance in the surgical patient for many reasons, not only because it may be associated with pulmonary edema and because it delays healing (20), but also because it may be present in the mucosa of the intestinal tract, which interferes with normal gastrointestinal function and often produces obstruction at a gastrointestinal anastomosis (21). This was first observed by Jones and Eaton (22) in 1933. Other clinical manifestations of protein deficiency are asthenia, anorexia, hepatic impairment, defective wound healing, and increased susceptibility to shock and certain infections, notably tuberculosis.

Therapy of Protein Deficiency. Nowhere is it more true than in protein nutrition, that an ounce of prevention is worth a pound of cure. Protein deficiencies may be prevented, first of all, by avoiding protein starvation and, secondly, by replacing abnormal losses in the blood soon after they occur. Protein starvation can be avoided by ensuring an adequate nutritional intake from the very beginning of disease, using protein-containing liquid drinks, when necessary, or a parenteral intake containing amino acids (hydrolyzed protein), if indicated. Deficiency due to abnormal blood losses can, of course, be prevented by adequate and prompt transfusions.

To correct existing tissue protein deficiencies, amino acids are required either from digested protein taken by mouth or given as such intravenously. Existing blood protein deficiencies, however, are much more readily and rapidly (even though temporarily) corrected by transfusion, particularly in preparation for operation. Significant tissue protein deficiencies require large amounts of protein, often up to 1,000 gms. or more, amounts which call for "hyperalimentation," often by tube feeding. This is usually impossible before most abdominal operations and must await the removal of the gastrointestinal lesion before full restoration is possible. In such a case the oral route can then be used. The parenteral channel is indicated whenever the gastrointestinal tract cannot or should not be used. For the correction of large tissue protein deficits, parenteral protein feeding is somewhat limited in scope, although the equivalent of 75 gm. per day can be given without too much trouble. While it is possible to prevent further tissue protein depletion in this manner one can, at most, expect only moderate correction of existing deficiencies. Moreover, it is a good policy to avoid complete protein starvation by adding a protein hydrolysate to the usual intake of water, glucose, and vitamins. This is especially true of the depleted patient being prepared for operation and even for the well-nourished patient requiring parenteral alimentation for more than a day or two after operation. Protein feeding with the intravenous infusion of amino acid mixtures is just as physiologic as the infusion of glucose; both are temporarily indicated whenever the gastrointestinal tract cannot or should not be used.

Completing the intravenous diet by the addition of protein food in this way was introduced (23) nearly 20 years ago. It has already been used extensively and may now be considered as a routine method of therapy for those unable to take any food by mouth. The principles involved are the same as those in the patient with severe anorexia, yet able to take a liquid diet by mouth. Protein starvation, regardless of its cause, promotes anorexia (24) and thus prolongs healing as well as convalescence. Extensive clinical experience has shown the importance of maintaining an adequate protein intake from the beginning of disease, an objective which is now a relatively simple matter whether or not the patient can take enough protein by mouth.

Plasma or blood transfusions also provide protein through the intravenous channel largely as a means of correcting chronic hypoproteinemia and anemia. Blood and plasma can also correct tissue protein deficits by a roundabout metabolic pathway, aided by tissue proteases which break down the plasma proteins or hemoglobin molecules, after they leave the blood stream, into their constituent amino acids which are then used by the tis-

sary, for the effective treatment of the patient whether operation is performed or not.

While the operation in most cases demands first consideration, many of the nonoperative procedures are sometimes *of equal importance* in securing a successful end-result. Most of these procedures, including the administration of drugs, should be used with the realization that their effects are not always predictable. For this reason, much commonly used therapy should be regarded as experimental. If this is done, it will soon be apparent that there are great *individual variations* in the response of patients, even of the same sex, age, and size—variations which are due *to many factors, some unknown. By combining* careful observations with the experience of others, one can establish the value or lack of value of each type of therapy. Although principles are really more important than details and must never be forgotten, it is really a combination of attention to scientific knowledge and the findings based on clinical experience that will permit each physician to reach the highest level of therapeutic efficiency. This approach will be used in the following discussions.

Rest: General and Local. Rest is probably one of the oldest single agents used in the treatment of surgical disease. Although its useful application is often taken for granted, there are many disadvantages which must be recognized. Thus, rest should not be employed when not indicated, nor for too prolonged a period. Both the advantages and disadvantages of general and local rest will be emphasized in the following discussion. In many instances rest may be modified or combined with limited motion, thus utilizing the benefits of each.

General rest means complete confinement to bed. In most cases movement in bed is permitted and, in fact, encouraged.

General rest implies not only physical rest of the body as a whole, but mental rest as well. The latter is often overlooked or its significance minimized. Surgeons are apt to forget the influence of mind over matter. Yet there is ample evidence that the patient whose fears have been allayed, whose muscles are relaxed, who sleeps well, has no pain, and has implicit faith in his doctor, will combat the effects of infection and injury much better than one who is apprehensive, tired, and worried. Ignorance itself is an important element in fear. All of these factors must be considered by the surgeon in planning his *general therapeutic program. The many im*plications of psychogenic factors in surgical diseases have been discussed by one of the authors in a text on surgical care (28).

Although general rest implies complete bed rest, it may be modified by permitting bathroom privileges, or the use of a commode in order to avoid a bed-pan and urinal, which may be annoying, particularly to male patients. Most surgical patients, though at rest in bed, should be encouraged and even or*dered to move their extremities and to do* deep respiratory exercises. The former will combat the tendency to deep plantar vein thrombosis (which often sets the stage for fatal pulmonary embolism) probably as effectively as early ambulation. Moreover, muscular movements minimize atrophy of disuse, anorexia, certain cardiovascular changes, and invalidism. Deep respiratory movements increase pulmonary ventilation and thus combat the tendency toward passive hyperemia of the lungs and postoperative atelectasis.

Local rest means rest of an individual part or system and may be used either alone or in conjunction with general bed rest. Narcotics add much to comfort of patients but they depress respiration and the cough reflex. A tight chest binder reduces pain by limiting respiratory movement in fractured ribs, yet in doing so actually permits full aeration of the lungs. The gastrointestinal tract is put at rest by ordering "nothing by mouth" in order to limit the degree of intestinal movement. In the case of the stomach, however, the situation may be different, at least in the presence of an active peptic ulcer. In this case, gastric peristalsis is generally increased when the organ is empty, which may be harmful by increasing pain and bleeding. For this reason the ingestion of food, particularly food containing fat, decreases gastric peristalsis and tends to minimize pain and further bleeding. At the other end of the gastrointestinal tract, defecation can be prevented by the use of constipating drugs while rectal wounds are healing.

Local rest of a part is used chiefly in cases of infection of, and injuries, fractures, and

Two general channels are commonly used for parenteral injection or infusions: one is subcutaneous (hypodermoclysis) and the other intravenous. Since each requires the use of the hollow needle, the details are discussed under that heading.

The *various fluids* which are commonly used, singly or in combination, for parenteral injections are: 1. whole blood; 2. plasma; 3. pure human serum albumin solution; 4. packed red cells; and 5. aqueous solutions containing (*a*) sodium chloride, bicarbonate (or lactate), and phosphate, (*b*) potassium chloride, (*c*) calcium gluconate, (*d*) glucose, fructose, or invert sugar, (*e*) amino acids (hydrolyzed protein), (*f*) fat emulsions, (*g*) ethyl alcohol, and (*h*) vitamins. Many of the electrolyte and carbohydrate solutions are used in various concentrations to meet different conditions. With such a wide variety, it is not surprising that many physicians find the field of parenteral alimentation complex and sometimes baffling. As already discussed, the problem is most readily solved by attention to the patient's history, to a knowledge of the principles of prevention, and to accurate replacement of specific deficits. Plasma and whole blood are often used to correct hypoproteinemia. When the erythrocyte count approaches normal, blood can no longer be used. As much as 500 ml. of plasma can be given per day, but if more than this is given in a 24-hour period, it will be utilized very inefficiently.

At times, it is essential to make up deficits rapidly. The best example of this is the use of plasma and blood transfusions following hemorrhage or traumatic shock due to loss of blood and plasma, where a delay of an hour or two may be responsible for irreversible circulatory failure and death. A second example would be severe dehydration in which water and salt may have to be injected rapidly when the patient is in a critical condition. However, in such cases the need for speed may be less important than the fact that the gastrointestinal tract is obstructed and cannot be used. When *acidosis or alkalosis* is present, rapid administration of parenteral fluids may be indicated. Ordinarily as dehydration is corrected, resumption of renal activity soon rids the body of excessive acid or base, as the case may be. Occasionally, however, the action of the kidneys is too slow or is handicapped by impaired renal function, and special solutions must be used. This is particularly true of metabolic acidosis, which is relatively easy to combat by the intravenous infusion of sodium bicarbonate or sodium lactate. Acidosis may be detected and measured readily by the degree of fall in the carbon dioxide component of the blood (*normal—50 to 60 volumes per cent or about* 25 mEq. per liter). It is more frequently recommended that sodium bicarbonate or sodium lactate be added to all saline solutions in the proportion normally present (1:3) in the extracellular fluid. Such a solution represents a true physiologic saline solution. Alkalosis seldom requires intravenous acidic (e.g., ammonium chloride) solutions because ordinary therapy usually suffices. Moreover, alkalosis is seldom associated with acute circulatory impairment, metabolic disturbances, or renal dysfunction. As already mentioned alkalosis associated with hypochloremia and hypokalemia responds to potassium therapy.

Often indeed, the parenteral administration of fluids is *the only or the most effective method* of therapy. The best example of indication for the parenteral route is the need for maintaining nutritional intake immediately after operation when oral intake is impossible or is interrupted lest it induce vomiting and distension. Parenteral feeding is also similarly indicated in preparing the depleted patient for operation even though only partial or temporary correction may be possible unless a moderate amount, at least, can be taken by mouth. A third example concerns any patient, medical or surgical, in whom oral ingestion of fluid provokes vomiting, distension, or severe diarrhea, or is injurious because of the need for temporary gastrointestinal rest. Parenteral alimentation may also be necessary in a few cases where there is faulty assimilation of food taken by mouth.

With the availability of amino acids and pure vitamins, an almost complete parenteral diet can now be given. This advance permits the patient to clear temporary nutritional hurdles without starvation.

SURGICAL METHODS

Besides operative therapy, numerous *surgical methods* are available, and in fact neces-

applied when swelling is already pronounced may lead to inadequate immobilization when the swelling subsides. Both can be avoided by frequent observation and adjustment. The Thomas splint is especially useful for immobilizing the upper and lower extremities and will be described later under fractures.

4. *Plaster casts* are commonly used for immobilization in fractures not only of the extremities but also of the pelvis, spine, and neck. The term *hip spica* is used when the lower torso and leg are encased, thus immobilizing the hip. A *shoulder spica* is a similar arrangement about the upper arm and chest. A plaster cuirass is a body and neck cast used to immobilize the cervical spine, because it looks so much like the metal breastplates worn by the ancient knights. Plaster casts may soften from use or by soiling and may have to be replaced.

Plaster casts, perhaps because of the high degree of immobility produced, are much more likely to promote atrophy of disuse. This may be minimized by splitting the cast in half (bivalving), thereby allowing motion under control for short periods between which immobilization continues. Splitting of the cast may be necessary for dressing wounds and occasionally because of circulatory impairment, which should be expected whenever swelling occurs after the cast is applied. The toes or fingers distal to the cast must be observed for 24 hours. Coldness, tingling, numbness, blanching, and cyanosis are manifestations of circulatory impairment. On the other hand, plaster applied when swelling is maximal may become too loose to immobilize the part when the swelling subsides.

Bandaging. Bandaging, once a sort of minor art in surgery, now deserves no such designation. The technic of bandaging with the older roller gauze made of thick muslin required special training, and courses in bandaging were given in most medical schools. With the advent of the thinner gauze bandage the situation changed. Bandages used at present are applied with much greater ease and really require no special technic. A bandage serves the purpose not only of rest and immobilization, but also of holding dressings in place and of protecting wounds against contamination. Bandages over exposed parts of the body also minimize heat radiation, thus inducing a higher local temperature which aids repair by increasing local blood flow. Bandages may be made of rolls of gauze, muslin, linen, or synthetic materials. Wide strips (binders) are used around the chest and abdomen. A popular form of binder is the many-tailed or scultetus binder. The sling has already been described.

There are many types of bandages which can be applied with a roll of gauze (Figs. 6, 7, 8). The *circular* or *spiral bandage,* as its name implies, is used to cover the sides of an extremity or finger. If the tip of the finger is to be covered or an amputation stump dressed, recurrent layers are first placed over the end and the dressing called a *recurrent bandage*. The *figure-of-eight* is a widely used type which consists of two crossed loops of gauze. When used to immobilize a joint—as the knee, elbow, or ankle—the loops are placed on either side of the joint. When the loops are passed around each shoulder, crossing between the scapulas, traction can be applied to the clavicles. This is a useful bandage for fractures of the clavicle. A *gauntlet bandage* is really a figure-of-eight in which one or more fingers are embraced in one loop and the wrist by the other, the bandage crossing over the dorsum of the hand. A *spica bandage* is applied in a manner similar to a plaster spica, as already described, but gauze alone is used.

Special bandages go by the names of their inventors. Thus *Barton* described a head bandage in which the roll of gauze is made to form three loops, one encircling the head longitudinally in front of the ears, the second horizontally just below the lip, including the chin and passing below the ear, and the third obliquely joining the first two and passing from the top of the head around the occiput. It is used in various head injuries. A *Velpeau bandage* serves to bind the arm to the chest and to elevate the arm. The hand is first placed on the opposite shoulder, the elbow resting against the chest wall. One turn of gauze passes around the shoulder and the flexed elbow, the other encircles the arm and chest. However, this dressing or bandage is so uncomfortable that it is now used only occasionally.

Heat and Cold. One must distinguish between the effects of heat and cold. The latter



Fig. 4. The proper method of applying a sling in order to produce rest and elevation of the forearm in an ambulatory patient. More elevation of the hand may be obtained by tightening the sling.

sprains to an extremity. Complete immobilization may be indicated, although lesser degrees of immobility are often sufficient. Historically, lively controversies were frequent and perhaps still occur between the advocates of rest and movement. The topic is entertainingly discussed by Keith (29). Limitation of motion often controls pain immediately, relieves apprehension, reduces reflex vasospasm, and thus promotes blood flow. Moreover, in infection, mechanical spread of bacteria into adjacent tissues is minimized by immobility. On the other hand, local rest, if prolonged, leads to reduced blood flow, decalcification of bone, atrophy of muscles, and limitation of movements of joints and tendons which, in older individuals especially, may even be followed by complete and permanent disability of the part. This is called *atrophy of disuse*.

METHODS OF IMMOBILIZATION. The various methods used to achieve immobilization in order of the degree of their completeness are: 1. slings and other bandages; 2. adhesive strips; 3. splints, and 4. plaster casts. Bandaging in general will be discussed separately.

1. A *sling*, usually made of muslin, is the simplest way to rest the upper extremity (Fig. 4); it may be made to include the hand. With the corners of the sling tied tightly behind the neck, the hand and forearm may be brought high up on the chest, increasing the degree of immobilization and also producing elevation of the forearm. A useful modification of the sling is the so-called *collar-and-cuff* (Jones) *sling*, which can easily be adjusted to any length allowing any degree of flexion of the elbow.

2. *Adhesive strips* are used to immobilize the elbow in flexion, the ankle in either eversion or inversion, the patella (to a slight extent), the ribs, the pelvis, and sacroiliac joints. Adhesive is also used to hold dressings in place. Adhesive may produce dermatitis which can sometimes be avoided by using Scotch tape instead.

3. *Splints* are made of wood, metal, or plaster. The wooden boards are thin and cut to proper size and shape (Fig. 5). Padding is added to the side next to the skin. Such rigid support prevents motion and is especially necessary in bone and joint injuries. The danger of excessive pressure under splints is greatest when the part is immobilized before swelling occurs. On the other hand, splints

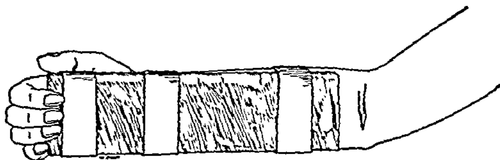


Fig. 5. Immobilization of the wrist and forearm by means of a thin board splint held in place by strips of adhesive.

applied when swelling is already pronounced may lead to inadequate immobilization when the swelling subsides. Both can be avoided by frequent observation and adjustment. The Thomas splint is especially useful for immobilizing the upper and lower extremities and will be described later under fractures.

4. *Plaster casts* are commonly used for immobilization in fractures not only of the extremities but also of the pelvis, spine, and neck. The term *hip spica* is used when the lower torso and leg are encased, thus immobilizing the hip. A *shoulder spica* is a similar arrangement about the upper arm and chest. A plaster cuirass is a body and neck cast used to immobilize the cervical spine, because it looks so much like the metal breastplates worn by the ancient knights. Plaster casts may soften from use or by soiling and may have to be replaced.

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A B

Fig. 6. Spiral reverse bandage of thigh. A, introduction of the first reverse; B, completed.

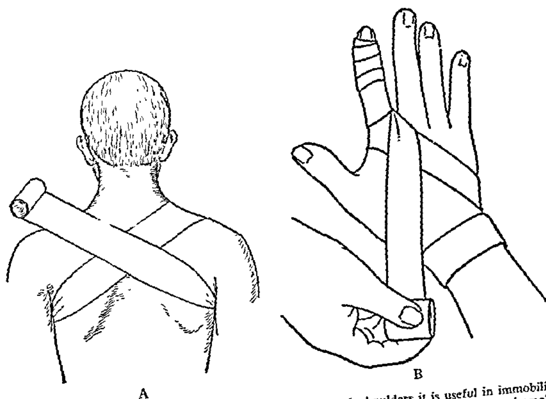


Fig. 7. Two types of figure-of-eight bandage. A, around both shoulders it is useful in immobilization in case of fractured clavicle; B, this type is also called a gauntlet bandage. The finger is kept immobilized in extension, flexion being restricted or impossible.

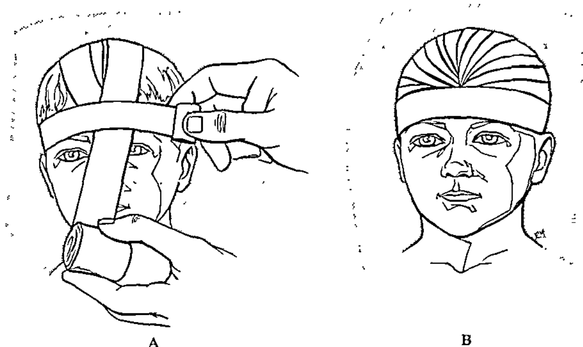


Fig. 8. Double roller bandage of the head. A, each circular turn of the narrower bandage fixes the reverse of the wider one on the forehead and on the occiput; B, completed. The Barton bandage is also used for dressings about the head; it is a more extensive bandage since it passes beneath the jaw and around the occiput.

deals largely with environmental temperature which is known to influence the outcome of certain diseases, particularly burns, shock, and extensive infections. Fever, which is discussed separately, produces some of the effects of high environmental temperature.

GENERAL EFFECTS. Environmental temperature varies widely in different parts of the world and at different seasons. Much has been learned of the physiologic effects of environmental heat by observations made during fever therapy and of cold by the recent studies on hypothermia (30, 31).

Although the sensible and insensible loss of water and electrolyte is greatly increased by high temperatures, the humidity and the movement of air must also be mentioned as factors. Insensible loss of water by evaporation through the intact skin and in the expired air contains no salt, whereas sweating by actual secretion contains a variable amount of salt, increasing with the rate of secretion from a low level toward, but not equal to, the concentration of salt in the plasma. Workers in high ambient temperatures may lose a maximum of 2 liters in 1 hour, as much as 10 liters in 24 hours (32). Fever itself has a similar influence on water and electrolyte metabolism. These factors are of obvious importance in providing the proper intake of water and electrolyte, as discussed later.

THE LOCAL EFFECTS. The local physiologic effects of heat and cold have been studied widely; the details may be found in many publications. One might summarize these observations briefly by saying that heat, either local or general up to 40° C. (104° F.), increases local blood flow, exudation, and cellular activity, imparting a local sense of warmth. Above this point, injurious effects on the tissues begin and increase progressively. Increased tissue metabolism even below this level may prove harmful when the circulation cannot keep pace, as in peripheral arterial disease or in shock. Local cold in general has an opposite effect to that of heat; i.e., there is a sense of cold and a decrease in blood flow, exudation, and cellular activity. As temperature falls progressively, anesthesia replaces the sense of cold and becomes more

and more pronounced, becoming complete slightly above the freezing point of water. At a point slightly below freezing, cell metabolism ceases and the cell dies. However, single cells, if carried rapidly through the freezing point to extremely low temperatures, maintain their vital potential indefinitely. When brought back through the freezing point at any subsequent time, life is restored and normal activity resumed. In this way viruses, bacteria, and even spermatozoa may be preserved for years (33).

As the local temperature falls progressively, the color of the skin becomes either pale or cyanotic due to increasing vasoconstriction. As the freezing point of water is approached, this effect, however, may be intermittent, alternating with waves of active vasodilatation and increased blood flow as shown by a pink color of the skin. Below the freezing point the blood coagulates, whereupon all blood flow ceases. Under these conditions, irreversible changes take place followed by thrombosis and necrosis.

The local effects of heat and cold are usually superficial, limited to a few millimeters below the surface, but deeper penetration is sometimes possible. This is true of certain types of heat, such as the infrared ray, diathermy, and radiothermy. Cold on the other hand, unless excessive in degree, is usually superficial.

Therapy with Local Cold and Heat. The application of wet, cold sheets or immersion of the body in cold water is useful in reducing an abnormally high temperature, particularly in patients with thermic fever. An ice bag is of value to relieve pain and to limit or halt exudation. Its value in acute infections is disputed. The authors feel that cold is apt to be injurious in severe bacterial inflammation. Certainly, excessive cold is prone to damage delicate tissues and is poorly tolerated by the very old and young. Its anesthetic effect is responsible for the absence of any warning stimuli before such damage is done. Local cold finds its greatest value prophylactically when used early to minimize edema following simple sprains, and to alleviate discomfort when applied locally, especially over deep-seated lesions. Refrigeration for a gangrenous infected extremity may be indicated in preparation for amputation (Ch. 18).

The frequent use of the ice bag in intraperitoneal inflammation, including acute appendicitis, is not only based on misconceptions but may actually lead to danger. The claim that cold aborts the inflammation is based on fallacious reasoning, since cold penetrates but a few millimeters below the skin surface. Moreover, its reputed inhibitory effect on intestinal peristalsis has not been substantiated by careful observation. Indeed, it has been shown that external cold actually stimulates gastrointestinal activity; inhibition is produced by application of heat (34).

Heat is of value in a wide variety of surgical conditions. In the treatment of infections it has been all but abandoned because of the dramatic effects of chemotherapy. Induced elevation of body temperature (artificial fever) has an established use in a variety of diseases but is no longer utilized because of the effective use of antibiotics. Local heat is useful because it imparts a sense of warmth which is appreciated in many painful lesions. Its greatest value, however, is the promotion of hyperemia and blood flow, and exudation and cellular activity in inflammation, thus aiding in nature's defensive reactions. Wet heat in the form of soaks or wet dressings is used especially in open wounds (Fig. 9); it aids in promoting discharges and in mechanically loosening necrotic tissue. Wet dressings should rarely be used for more than 24 or 48 hours because they lead to maceration of tissue. Dry heat is applied by means of a hot-water bottle, poultices of various kinds (which are changed as frequently as they cool), electric bulbs or pads, and infrared lamps or diathermy.

Transfusion. Richard Lower is credited with carrying out, in 1665, the first successful blood transfusion in dogs. Two years later, lamb's blood was injected into the vein of a human being for the first time; the patient recovered but was observed to pass urine "as black as soot" soon after, obviously hemoglobinuria resulting from hemolysis. Fatalities followed similar experiences whereupon the procedure was prohibited by law. One hundred and fifty years passed before transfusions were given from human to human by an English obstetrician, James Blundell. Safe use of the procedure, however, awaited the discovery of the blood groups by Landsteiner

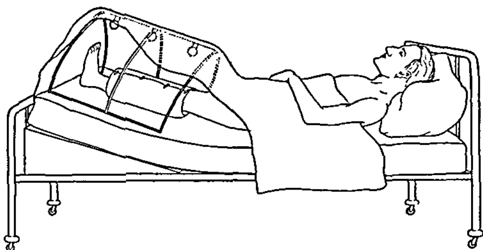


Fig. 9. A method of application of local heat to the lower leg by means of a cradle containing electric bulbs. Rest and elevation of the limb is also achieved.

(35) at the beginning of this century. For a long time thereafter, the inconvenience of giving blood directly from donor to recipient, often in the operating room, limited its application. With the introduction of citrate as an anticoagulant by Lewisohn (36) shortly before World War I, transfusions became so widely employed that blood banks are now maintained in practically all hospitals (37).

Transfusions are extensively used in surgical patients, most commonly to correct acute blood deficits. In general, transfusions are indicated: 1. To supply red cells after their loss by hemorrhage, in malnutrition, and in anemia from inadequate red blood cell formation, or abnormal loss through hemolysis. 2. To supply white blood cells in agranulocytosis, and platelets in thrombocytopenia; in both cases fresh blood must be used. 3. To supply one or more of the various protein fractions in the plasma, of which the most important are albumin, prothrombin, the unknown factor in hemophilia, and perhaps an antitryptic factor in acute pancreatitis.

Blood transfusions are most commonly and urgently employed for the correction of acute blood deficits produced by hemorrhage. The value of a transfusion after severe hemorrhage is greatly increased in direct proportion to the promptness with which it is injected after the loss. Speed and convenience have been greatly aided by blood banks, which have been set up in more and more hospitals during the past decade, and by the efforts of the American Red Cross. Blood banks, moreover, make it possible either to use whole blood or, by separating them, to use plasma and red cells separately. In the case of hemorrhage, whole blood is obviously the ideal replacement fluid, although plasma alone is preferable to red cells alone. However, injected plasma, because of its content of protein, maintains the normal colloidal osmotic pressure of the blood far better than saline. This, according to Starling's hypothesis, is the function upon which normal water interchange depends and is the property of blood which keeps it from escaping through the capillary wall thus maintaining normal blood volume without which circulation cannot be sustained. Plasma was used extensively as a whole blood substitute in battle casualties largely because of ease of storage and transportation, particularly when frozen or dried. It was later learned that such pooled plasma was a frequent cause of untoward reactions, particularly transmission of the virus of homologous serum jaundice. Indeed, much of the prepared plasma was eventually prohibited from clinical use and was made into various plasma protein fractions. Still later, safe plasma substitutes were developed, of which the most commonly used at the present time is a polysaccharide called Dextran (see page 255). The virus of homologous serum jaundice transmitted by plasma transfusions can be greatly attenuated or eliminated by

storage at room temperature (J. Garrott Allen).

During World War II, it was learned by actual experience that whole blood was so superior to plasma or plasma substitutes that the inconvenience of transporting whole blood and even the adverse changes during storage were accepted as minor disadvantages. Blood was either donated by civilians at home and sent by plane in a refrigerated condition to the far-flung theaters of war or obtained directly on the battlefield from convalescent soldiers or other personnel. Plasma, however, may be useful in many patients in shock who have not suffered loss of whole blood, but rather extracellular fluid containing varying amounts of plasma proteins. This is true in the case of severe hot-water burns, in peritonitis, and in extensive acute inflammation, for the lost fluid is essentially a 1 to 4 per cent plasma protein solution in physiologic saline. Ideal replacement therapy, therefore, consists not of saline alone, but of added plasma or some other colloidal solution. In such cases, hemoconcentration is often a guide to the amount of fluid needed for the correction of the deficit. On the other hand, whole blood is indicated for anemia which sometimes develops after several days in patients with burns. Many blood banks actually separate some of their whole blood into plasma and red cells, which permits one donation to serve more than one patient. It should be emphasized, however, that whole blood should be used when plasma is not available and vice versa.

For the prompt and often lasting correction of anemia of various types, whole blood transfusions (or packed red cells) are commonly used. A simple method for giving packed red cells is to store an inverted bottle of blood several hours, maintaining this position during transfusion until the cell-plasma interphase is reached. The red cells from 1 liter of blood will usually increase the red count by 500,000 to 800,000 cells per cubic millimeter, or the hematocrit by 5 to 8 per cent, unless there is further or continued loss of red cells. In acute hypoproteinemia occurring in conditions other than hemorrhage—as general peritonitis, intestinal obstruction, extensive tissue inflammation and exudation—whole blood and plasma are each effective. Here too, as in shock, the question of using whole blood or plasma depends upon what is lost and the relative concentration of the red cells.

In chronic anemia and hypoproteinemia of nutritional origin, whole blood and plasma are both useful and clinically valuable, particularly in preoperative preparation. They may even be needed when there is a normal concentration of hemoglobin and plasma proteins, provided the total blood volume is low. Blood volume measurements, however, require an exact technic which must be interpreted correctly. As the sole source of parenteral protein feeding, blood or plasma is inconvenient, expensive, and unphysiologic as compared with amino acid mixtures.

The technic of obtaining whole blood and the various precautions necessary for the establishment of a blood bank are now so well known that the details will not be described (Fig. 10).

The Hazards of Blood Transfusions. The dangers of blood transfusion must be emphasized (38), for with the development of blood banks has come a tremendous increase in the use of whole blood. Despite the most careful and meticulous technic, untoward reactions following transfusion cannot be entirely eliminated and, indeed, may reach an incidence of 3 per cent. Most of them, fortunately, are pyrogenic and of little consequence, but a few are due to incompatible blood and are serious. Moreover, under the best conditions, the procedure carries with it a certain mortality, though perhaps not more than one in 3,000 transfusions. The danger of reaction is greatly increased when multiple transfusions are indicated, in that each unit given must be compatible, not only with the patient's blood but with each unit given previously or subsequently. The possibility of transmitting the virus of homologous serum jaundice must also be recognized as a potential hazard.

For these and many other reasons, transfusions should be given only when definitely indicated and the amount limited to that actually needed. For example, transfusion is not necessary as routine during operation for a fall in blood pressure due to neurogenic factors or to the position of the patient. Another



Fig. 10. A method for obtaining blood from donor. Note that this is a closed system. The airtight flask contains the proper amount of citrate solution (50 ml. of 2.5 per cent for 500 ml. of blood) and is sealed with a partial vacuum so that the flow of blood is automatic and does not depend on gravity or the positive venous pressure to fill the bottle.

example, blood transfusion should not be given before operation merely because the hemoglobin report is a little low in a patient in good general condition who has had no evident blood loss. In such a case, repeating the laboratory test may be a much easier way of correcting a suspected deficit. Still another example is the needless use of blood to replace moderate loss during operation, in patients whose normal regeneration processes can be counted on to correct the deficiency during the postoperative period. This is particularly true in *radical resection of the breast* in a healthy woman. In many cases more blood is used than is actually necessary. The amount of blood transfused should be judged by the amount that has been lost. If it is clear that only 1 liter has been lost, 2 or 3 liters should not be given just because the blood pressure has not been fully restored. The surgeon and the anesthesiologist, in such a case, must look for other causes for hypotension and control the almost automatic impulse to give more and more blood. The danger of excessive transfusions in producing myocardial imbalance has been well documented by Holden and associates (39). Although it is also known that the mortality rate is high in patients with myocardial disease having major operations, it will be much higher if blood in proper amounts is not given (40).

Serious untoward reactions due to incompatible blood are usually hemolytic and, in an unanesthetized patient, are ushered in by the almost immediate appearance of profound dyspnea, cyanosis accompanied by smothering sensations, and severe pain in the chest or back. Should any of these manifestations *occur during the beginning of the transfusion*, the procedure must, of course, be stopped at once. In some cases, chills and fever occur, followed by acute renal shutdown (Fig. 11). Death may result immediately or in several hours, accompanied by shock, or days later by uremia. If there is any question as to a reaction, hemolysis should be suspected and a specimen of blood spun down and examined for hemoglobinemia. The urine should also be examined for hemoglobinuria. Later, hemolysis is revealed by the development of jaundice. An untoward reaction during operation produces fewer but more serious mani-

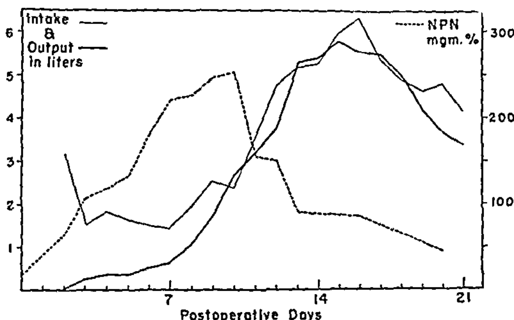


Fig. 11. Postoperative anuria due to transfusion reaction. Note the steady increase in the plasma nonprotein nitrogen and its fall only after diuresis had reached and exceeded 3 liters of urine a day. The daily fluid intake was kept under 2 liters during the oliguric phase, i.e., until about the seventh postoperative day, when it was increased parallel with the increasing diuresis. Note that 6 liters of urine was excreted on the sixteenth day. This large output was necessary to excrete all the accumulated nitrogenous waste products. Not shown is a progressive rise and fall in plasma phosphate which paralleled the nonprotein nitrogen. The plasma potassium rose to 7 mEq. per liter (27 mg. per cent) on the ninth day, although the electrocardiogram showed no change, and promptly returned to the normal of 4 mEq. (15 mg.) a week later. The plasma chloride was low (80 mEq. per liter or 284 mg. per cent) on the sixth day and returned to normal slowly by the sixteenth day, long after the diuresis was established. The plasma sodium level fell (to 125 mEq. per liter) with the chloride but returned to normal much more rapidly. Restoration of Na^+ and Cl^- was aided by increasing the salt intake during the period of recovery. In this case there was no change in the plasma bicarbonate content.

The patient made an uneventful recovery; two months later his kidney function was studied and found to be normal. (From Elman, R. Surgical Care, Appleton-Century-Crofts.)

festations. Failure of the blood pressure to respond to the transfusion, a dusky color of the skin, and an increase in oozing from cut tissues everywhere are usually present. Diagnosis can be confirmed by finding hemoglobin in the plasma or in the urine. Increased oozing may also occur after massive transfusion of compatible blood. Since platelets disappear from stored blood in a matter of days, this platelet deficiency may be responsible for the bleeding which can be corrected by substituting fresh for stored blood. Other causes for such oozing may be an increase in fibrinolysin, more recently called plasmin, a proteolytic ferment which dissolves blood clots; it is treated by administration of fibrinogen. Profuse bleeding may also be caused by hyperheparinemia. The etiology of this condition is not clear insofar as there is no agreement as to whether or not the causative agent is really heparin but a heparinlike substance. However, the condition may be treated effectively by protamine or toluidine blue.

Other serious reactions may be due to the accumulation of unmetabolized citrate, to contaminated blood, to allergic reactions which may even result in anaphylactic shock, to circulatory overloading, and to air embolism from careless use of positive air pressure. Homologous serum hepatitis may occur later; hemosiderosis, still later. Less severe untoward reactions after transfusion are usually pyrogenic and in general are not serious.

Mention should be made of the influence of the Rh factor (41). Rh refers to an antigen present in the blood of most humans; it is so called because it also is found in the red cells of the monkey (*Macaca rhesus*). Reactions due to the Rh factor may occur because a few individuals do not have this antigen, i.e., their

blood is Rh-negative. Should they receive blood from an Rh-positive donor they may become sensitized so that subsequent transfusions with Rh-positive blood may produce a severe hemolytic reaction similar to that observed with incompatible blood. Inasmuch as it is possible to test for the presence or absence of the Rh factor, it is obvious that any patient with Rh-negative blood will require the selection of an appropriate donor who also has Rh-negative blood. Untoward reactions have also been ascribed to the added citrate, especially when large amounts of blood have been given (42). A complete discussion of the various dangers will be found in texts devoted to the details of transfusions.

The treatment of severe transfusion reactions depends on the cause. An injection of 10 ml. of a 10 per cent calcium gluconate solution has been recommended, especially for hypotension; it presumably reacts by removing excess ionized citrate (43). Acute anemia may call for the transfusion of washed, fresh red cells. Other therapy includes antibiotics for contaminated blood; cortisone for severe, benadryl for less severe, allergic reactions; venesection for overloading.

The usual amount of blood which can be safely drawn from the average adult donor without symptoms of hypovolemia is 500 ml. In most cases much larger amounts are required, which means the use of several donors. On the other hand, in babies and children, the amount may be much less than 500 ml.

Refusion is another term for *autotransfusion.* When severe intraabdominal hemorrhage has occurred, from trauma either before operation or during operation, it is sometimes possible to save much of the spilled blood and inject it into the patient's vein. When a gunshot or stab wound has severed a large vessel and also perforated a viscus so that the blood is mixed with urine or intestinal contents, refusion should not be done except in a dire emergency. However, years ago, before blood was so readily available from a blood bank, such contaminated blood was used occasionally, and without any untoward results. In refusion, the spilled blood is collected in a basin containing sufficient sodium citrate to prevent clotting. Suction has the disadvantage of breaking up the red cells. The blood is then strained through several layers of gauze and given intravenously. Isotonic saline and glucose may be added to augment the fluids. Because of the availability of blood banks and various blood substitutes, refusion is seldom necessary at the present time, but more use should be made of uncontaminated blood when found free in the peritoneal or thoracic cavity at the time of operation for injury. The use of blood substitutes is discussed elsewhere (p. 255).

Resuscitation. Resuscitation, which really means the restoration of life, may be necessary in case of sudden respiratory failure (asphyxia) or circulatory failure (cardiac arrest). These often occur simultaneously or follow each other within a matter of seconds. Speed is the essence of resuscitation which can be successful only if carried out within a very few minutes and if there is no irremediable organic basis for the accident. Various methods of resuscitation are discussed by Saklad (44). Respiratory and cardiac emergencies are also discussed in Chapter 11.

Artificial respiration is indicated when breathing stops suddenly, whether from drowning or other causes. Treatment for cardiac arrest when present must be carried out simultaneously. Regular inflation and deflation of the lungs are obviously required so that interchange between the lungs and outside air may occur. The upper airway, of course, must be patent and to insure this, the tongue and jaw must often be drawn forward in order to prevent obstruction of the pharynx.

Interchange is brought about by one of two general methods. 1. Air is forced intermittently into the lungs, allowing the elasticity of the chest wall to expel it on the release of pressure. This is the principle involved in mouth-to-mouth insufflation or with the bag of a gas anesthesia machine. The latter method is a simpler method, but the equipment will rarely be available except for emergencies occurring in the operating room. Accordingly, the mouth-to-mouth method is being recommended for use outside the operating room, particularly since it is so effective (Gordon et al.). (Fig. 12.) 2. Air is forced out by external compression of the chest wall, thus allowing air to enter on release of pres-

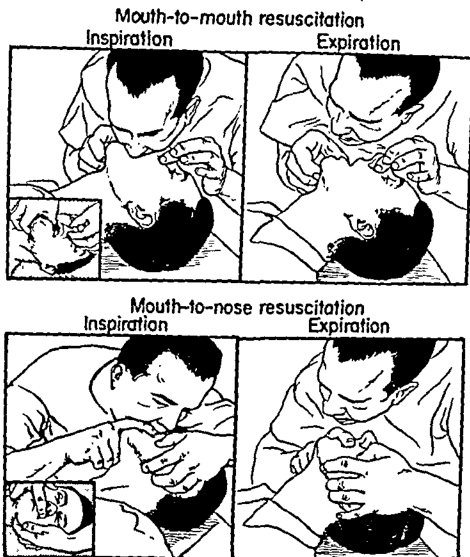


Fig. 12. Technics for mouth-to-mouth and mouth-to-nose resuscitation. (From Gordon et al., J.A.M.A.)

sure from elastic recoil of the thoracic cage. This principle can be applied to the patient in both the supine (face up) and prone (face down) positions. In the former, the greatest expansion of the chest is produced by first extending the arms overhead. Expiration is then effected by bringing the arms down and compressing them against the chest. When possible, however, the prone position as in the Nielsen method (Fig. 13) is preferable, inasmuch as it allows the tongue to drop forward, thus keeping the air passage open. This position also aids in the expulsion of vomitus which might otherwise be aspirated, especially by a comatose patient whose tongue would otherwise fall back, producing obstruction. The prone position also tends to aid the drainage of water from the lungs in drowning, although there is now evidence that on most occasions little or no water is present in the pulmonary tree of the drowned person.

When an organic obstruction is present, artificial respiration is obviously useless. Such an obstruction, usually at the larynx, is first manifested by the patient's extreme restlessness. The diagnosis becomes more obvious later because of the forceful attempts on the part of the patient to breathe, during which time he uses all of the accessory muscles of respiration, including the neck muscles. In such an event it is mandatory to resort to tracheotomy or laryngeal intubation as an emergency. The use of drugs such as caffeine and lobelin is of no proved value, although there is no harm in their use, especially the former. There is no evidence that they can

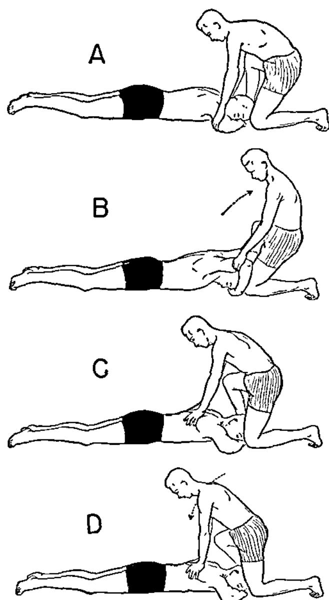


Fig. 13. The Nielson arm-lift back-pressure method of resuscitation. The Nielson method of artificial respiration as illustrated above is about equal in efficiency to the back-pressure hip-lift method but is easier to execute. The mouth-to-mouth method is equally effective and actually has certain advantages over this method. (From Gordon et al., J.A.M.A.)

start respirations which have ceased. When respirations are weak and shallow, the use of carbon dioxide as a respiratory stimulant is advisable, particularly for shallow postanesthetic breathing and in carbon monoxide poisoning. It is given mixed with a high concentration of oxygen.

Artificial respiration, when successful, should be followed in a few minutes by spontaneous breathing. If artificial respiration is required for several hours, the Eve method is recommended but requires an elaborate tilting device to permit alternate change from the head down to head up position. In this way, the abdominal contents pull and push on the diaphragm and produce respiratory exchange. The mouth-to-mouth and Nielsen methods are simpler and achieve the same result. The electrophrenic method of Sarnoff (45) is ingenious, simple, and apparently quite effective. If artificial respiration is required for long periods because of muscular

paralysis, as in acute poliomyelitis, various types of respirators are available.

After sudden *cardiac arrest*, the simplest procedure, which is occasionally effective, is thumping the precordium, combined with vigorous artificial respiration, since asphyxia nearly always accompanies cardiac arrest. *Puncture of the heart* with injection of adrenalin has apparently been responsible for saving many lives, but *manual massage of the heart* is the most successful method of starting the stopped heart and can readily be done during the course of an abdominal operation through the diaphragm or, more effectively, by means of an intercostal incision made over the precordium. Massage should be slow, rhythmic, and gentle; electric shock with especially prepared electrodes is indicated in the presence of ventricular fibrillation. Artificial pacemakers may also be of value. The incidence of cardiac arrest during operation, however, can be greatly reduced by meticulous and constant care during the anesthesia, with special attention to avoid hypoxia. These and other features of resuscitation more directly connected with anesthetic complications are discussed in Chapter 11, on anesthesia.

Whatever is done in the case of cardiac arrest must be done within a matter of four minutes, since cardiac arrest for longer periods produces permanent cerebral damage and may be incompatible with life. On the other hand, the decision to open the chest and massage the heart requires critical judgment.

The Hollow Needle. The origin of the hollow needle is clouded in the dim mists of antiquity, although it is probable that goose quills were used by savages and bronze tubes by the ancients as trocars for the evacuation of fluids in the chest or abdomen. For example, Hippocrates employed a small tube in empyema and mentioned beveling its edge, although an incision was first made between the ribs. Celsus wrote of a cannula for draining ascitic fluid. The syringe itself is of more recent origin. Abulcasis, an Arabian physician about A.D. 1000, is credited with the first description of a "cannula" which contained a plunger of copper armed with cotton and was used to irrigate the external auditory canal. A goose quill attached to a pig's bladder was used in 1658 to inject medicants into the vein of a dog for the first time by no less a person than Sir Christopher Wren, the famous English architect and astronomer whose greatest fame is enshrined in St. Paul's Cathedral, in London, which he designed. The modern hypodermic needle to introduce drugs is said to have been developed only as recently as 1834 by a Dr. Alexander Wood of Edinburgh. In its present form the needle is made of stainless steel with or without a stilet and with sharp, beveled edges to permit easy introduction. It is also made in a great variety of sizes for various purposes.

The hollow needle may be used either to introduce or withdraw fluid or air. The injection of fluid may be intradermal, subcutaneous, intramuscular, intravascular (Fig. 14), intraspinal, or into serous cavities, joints, or other spaces. Withdrawal of fluid is spoken of as aspiration and sometimes as tapping. Needles are used to aspirate fluid from the peritoneal cavity, spinal subarachnoid space, the cerebral ventricles, cisterna magna, pleural space, joints, and from abscesses or cysts. In solid tumors of doubtful nature, large needles are often useful in actually removing a core of tissue for microscopic examination and diagnosis. This procedure, however, must be used with caution when malignant tumors are suspected because of the danger of local spread.

1. *Intradermal injections* are made with a fine hypodermic needle to introduce novocain for local anesthesia, or such biological materials as tuberculin or scarlet fever antigen, for diagnostic purposes. A raised wheal is formed when the material is injected into the derma.

2. *Subcutaneous injections* with small hypodermic needles are made for the administration of most drugs (morphine, atropine, and so forth). When large amounts of fluid (saline) are injected, a larger and longer needle is employed. This procedure is called hypodermoclysis and was formerly a popular, though now uncommon, method of giving parenteral fluids.

Hypodermoclysis has obvious advantages over intravenous infusions, which will be discussed separately. There is no problem of venous puncture and no danger of pyrogenic reaction or thrombophlebitis. On the other hand, hypodermoclysis may be painful if

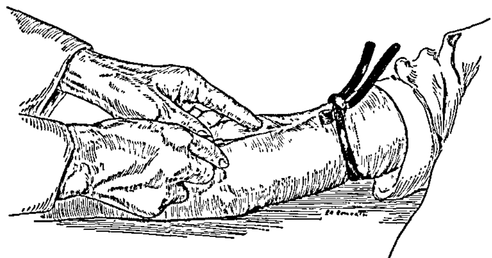


Fig. 14. The proper method of performing a venipuncture for the withdrawal of blood or for intravenous medication. The tourniquet is placed to bring the veins into bold relief; it is removed as soon as the vein is entered, as indicated by the free flow of blood into the syringe.

given too rapidly, may introduce infection if not given aseptically, and has other more specific limitations which are discussed below. Common sites for subcutaneous infusion are the axilla, which contains a good deal of loose areolar tissue and is richly supplied with lymphatics for rapid absorption, the inner side of the upper thigh, the lower abdomen, and the groin. Subfascial and intramuscular infusions have also been recommended, but are more apt to be painful and are now seldom employed. Hyaluronidase, as a spreading agent, is sometimes added and does diffuse the injected fluid over a wider area of the subcutaneous space. This tends to prevent the pain due to rapid accumulation of fluid at one site, thus shortening the total period of injection. Saline solutions may, perhaps, be absorbed more rapidly with hyaluronidase, but other solutions such as glucose are not (see below).

The absorption of isotonic saline solution is now known to occur progressively from the time the infusion is started. Solutions containing glucose or amino acids, though isotonic with the body fluids, behave quite differently. Both experimental and clinical studies have shown (46) that equilibrium between such solutions and the extracellular fluid must first be established before absorption begins. During this process, water and salt move into the subcutaneous space containing the glucose, depleting to that extent the extracellular fluid. The reasons are as follows: First of all, glucose and amino acids are larger molecules and, hence, move much more slowly than do sodium and chloride ions; and second, unlike sodium chloride, the concentration of glucose, even when isotonic (5 per cent), is 50 times its concentration in the extracellular fluid. Thus, the period of time required for equilibrium and total absorption may be prolonged from about seven hours, which is the average period in the case of isotonic saline, to 24 hours or more. These factors may not be significant in patients with a normal circulation and satisfactory water and electrolyte balance. In ill persons, however, the situation may be quite different in that the temporary withdrawal of water and salt into the subcutaneous space may lead to peripheral circulatory impairment.

3. *Intramuscular injections* are absorbed more rapidly than those into subcutaneous tissue, but may be used only when the amount of fluid is small (up to 5 ml.). The deltoid and gluteal muscles are the usual sites, care being taken to avoid nerves and large vessels.

4. The *intravascular route* may be intravenous or intraarterial. *Venipuncture* is used for the aspiration of blood as well as for the injection of fluids directly into the blood stream; it must be done with a fairly large needle for the former, a smaller one, for the

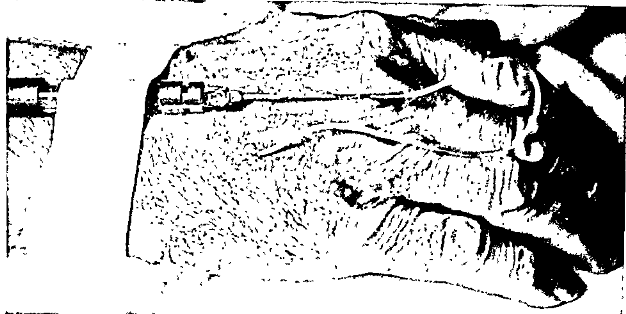


Fig. 15. Continuous venoclysis. The patient was a 75-year-old salesman. Following a sudden attack of abdominal pain, he was explored, and a foot long segment of gangrenous bowel caused by a localized mesenteric thrombosis was resected and an end-to-end anastomosis performed. While he was still in the operating room under anesthesia, the tiny catheter was inserted into the vein through a needle, which was then withdrawn. Two liters of Amigen and glucose were infused by continuous drip every 24 hours. The rate of flow was controlled by adequate nursing care. The photograph was taken four days later, just before the tube was removed and after oral feeding was started. Ambulatory from the night of operation, the patient was also able to use both arms without difficulty. Recovery was uneventful.

latter. For aspiration of blood, the two veins at the fold of the elbow in the antecubital space are commonly employed, although either the femoral or jugular vein and, in infants, the superior sagittal sinus, may be the only ones through which blood can be obtained.

For intravenous infusion, small veins may be used, *including those over the forearm, the* wrists, the dorsum of the hand (Fig. 15) and about the ankle. One of the problems of intravenous infusion, particularly when used for days and weeks, is the thrombosis of successive veins, making them useless for further infusion. These thromboses are significant, *however, only when they produce systemic* manifestations such as chills and fever. Of the many factors involved in thrombosis, the following may be specifically mentioned: (*a*) *Speed.* The faster the infusion is, the greater the likelihood of thrombosis. For example, even large veins can be quickly obliterated with *1 liter of 10 per cent glucose given* over the course of half an hour or less, *whereas* no change will follow the same infusion given during one or two hours. (*b*) *Tonicity.* Hypertonic solutions such as 20 per cent glucose, particularly when given rapidly and in a small vein, are much more apt to produce thrombosis than isotonic 5 per cent glucose solutions. (*c*) *Reaction.* Veins are much more readily irritated during infusions of acid or alkaline solutions. (*d*) *The relative lumen of vein and needle.* Any needle *which occupies the entire lumen of the vein* is much more likely to produce thrombosis than a needle small enough to permit the flow of blood around it. It is probable that small hypodermic needles could be used more frequently, provided that the rate of delivery is increased sufficiently by the controlled use of *positive pressure.*

Continuous venoclysis with tiny plastic catheters has been recommended and fairly widely used (Fig. 15). In large veins, these catheters may be introduced through the lumen of the needle used for venipuncture, after which the needle is removed. In smaller *or deeper vessels, it is necessary* to cut down on the vein and tie the catheter in place. In either case, constant supervision is required to regulate the rate of flow. This method may,

however, be used intermittently by filling the tube with heparin solution in the intervals between infusions. Patients appreciate infusion through such a plastic catheter for it permits free movement of the part and, of course, eliminates repeated venipunctures. Slow infusion also improves the utilization of glucose and amino acids (47). The disadvantages are due to thrombosis, which can be minimized by observing the point of entrance of the catheter through the skin two or three times a day and removing it at the first sign of redness or local inflammation. Otherwise, thrombosis will be evident only when the patient complains of pain along the course of the vein or has unexplained fever; occasionally chills occur with local pain and redness over the vein. Venoclysis through one vein is possible for three or four days on the average, although sometimes for a week or more. After this time, of course, the catheter should be removed. A second vein then can be used for an additional period. Meticulous aseptic preparation of the skin at the site of the injection, or "cut-down," and careful cleansing of the catheter tend to prolong the time each vein can be used safely. In desperately ill patients, continuous intravenous infusion for longer periods of time may be so important as to justify inserting the catheter into the saphenous or femoral vein and passing it up into the inferior vena cava or into an antecubital vein, passing it down into the superior vena cava. Under these conditions, thrombosis is much less likely to occur and the infusion may be continued for much longer periods of time. The intrasternal route has also been used. Even the corpora cavernosa of the penis has been utilized for intravenous infusion.

Intraarterial puncture is now frequently utilized, especially for diagnostic arteriography.

5. The *intraspinal* (lumbar subarachnoid) space is often entered to obtain spinal fluid for diagnosis. Spinal puncture is also used to introduce anesthetic agents for spinal anesthesia, air (or often contrast media) for diagnosis by x-ray, and antibiotics in meningitis. Suboccipital (cisterna) puncture has also been used. The epidural space may be entered at the sacral notch or above to introduce anesthetic drugs for the production of regional (e.g., sacral or saddle) anesthesia.

6. *Peritoneal puncture* to obtain fluid for diagnostic purposes in obscure abdominal disease is being used more and more despite the apparently slight danger of perforating the lumen of the small intestine. As a means of introducing parenteral fluids, it is rarely utilized except in remote areas where other methods are not available. The hazard of intraperitoneal infusion arises not so much because of the danger of perforating the intestine, but because even isotonic saline solutions tend to produce a mild type of plastic aseptic peritonitis.

Paracentesis abdominis (peritoneal tap) is indicated to remove ascitic fluid in tuberculosis, peritoneal carcinomatosis, cirrhosis of the liver, or heart disease. A large, hollow needle (trocar) is used with a stilet in its lumen. The point of entrance is best prepared by making a tiny incision in the skin and fascia with a sharp, pointed blade.

The pleural space is entered for aspiration of fluid for diagnosis and treatment (paracentesis thoracis) and for the aspiration or injection of air (artificial pneumothorax).

The Catheter. A catheter is a tube, ordinarily flexible, which may be introduced into cavities for the purpose of draining or instilling fluid. Catheters used to be made only of rubber or of woven fabric. The newer plastics now are displacing rubber. For one thing, they are less irritating to tissue and to mucous membranes. They can be made of various plastics, each possessing specific and predictable properties such as transparency, consistency, stiffness, and maleability.

1. The *stomach tube,* for introducing fluid (gavage) or for removing fluids (lavage), is ordinarily used in one of two sizes. The large, more or less rigid stomach tube (No. 286) can be made to enter the stomach rapidly and is, therefore, of special value when rapid evacuation and irrigation of the stomach are necessary, notably after the taking of poison. A large tube also enables removal of thick or tenacious material in some cases of pyloric obstruction. The large tube may also be indicated in patients including the unconscious, who are unable or unwilling to swallow. It, of course, must not be used in those suspected of having ulcerated lesions, varices, or in those with heart disease.

In any case, the large tube is utilized temporarily and removed as soon as its purpose has been fulfilled.

The small tube (No. 16F) is used much more frequently. It is available in several forms, first as a simple catheter, with or without a metal tip, for continuous aspiration or feeding. For the latter purpose, tiny plastic tubes are now being used more widely. Another type of small tube is equipped with a balloon at the end, containing mercury, which enables the tube to pass more readily past the pylorus into the duodenum and small intestine for purposes of intestinal decompression. Still another type has two lumens, one for inflating the terminal balloon, the other for evacuation of intestinal contents.

2. The *rectal tube* is of the same caliber as the large stomach tube, but it is much shorter and is used to permit evacuation of gas (made difficult or impossible by anal spasm), to introduce solutions for absorption, to stimulate bowel movements, or to cleanse the colon with enemas. Rectal tubes do not pass above the rectum unless introduced into the sigmoid by a long proctoscope. Fluid in small amounts, about 200 to 300 ml., fills merely the rectum. In order to reach the cecum much larger amounts, several liters, are necessary. Perforation of the colon by introducing large volumes of fluid under pressure is an obvious mechanical danger which can be avoided by careful administration at low pressures.

To stimulate defecation, various solutions have been used; the procedure is classified as a low or high enema, depending upon the amount of fluid utilized. Ordinarily a small or low enema is adequate, for it is necessary merely to chemically stimulate the rectal mucosa. Of the many kinds of enemas, the following are probably the most common.

(*a*) *Soap suds* (ss) enema, consists of 1 liter (34 ounces) of warm tap water to which thickened soap has been added to produce a light suds. It is given slowly and the administration stopped at the first evidence of discomfort. If defecation does not follow, and the enema is retained, it must be siphoned off.

(*b*) *Magnesium sulfate, glycerine, and water* (mg&w) enema is smaller in volume but more irritating to the mucosa and, hence, often more efficient than an ss enema. Its composition ordinarily is as follows: 60 ml. of a 50 per cent solution of magnesium sulfate, 60 ml. of glycerine, and 60 ml. of water. A small glycerine suppository is simpler and, in about half the cases, just as effective as an enema.

(*c*) *Oil enema* consists of 100 to 200 ml. (3.5 to 7 ounces) of warm oil which is retained for several hours, presumably to soften a mass of impacted feces. It is then followed by an ordinary ss or mg&w enema. When the fecal impaction is hard and extensive, which is more common in children and in older individuals, mechanical removal must be employed, particularly when enemas fail.

(*d*) *Cleansing enemas* in large volume are often effective in removing fecal material from the entire colon in preparation for operation on the colon, particularly in children with megacolon. Tap water is potentially dangerous in this disease because enough absorption may occur to produce "water intoxication" which unfortunately has proved fatal in a few cases, especially when unrecognized and untreated by administration of salt solution. Isotonic saline should obviously replace tap water to prevent such a complication.

(*e*) *Other enemas*, such as those of milk and molasses or oxgall solutions, have the sanction of long tradition and are still used by a few older surgeons, although most of them are of historic rather than of practical interest.

3. *Catheterization* of the bladder is necessary in many conditions, such as prostatic obstruction and postoperative retention. In spite of aseptic precautions there is always the hazard of introducing bacteria and producing cystitis, a hazard which has been increased by the large number of antibiotic-resistant staphylococci now frequent in many hospitals. Careful technic must, therefore, be meticulously observed in all cases in order to reduce this danger to a minimum. The technic is described in Chapter 41.

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10

SURGICAL CONVALESCENCE

Preoperative Preparation
Postoperative Care

Convalescence, literally, *means growing* strong and, traditionally, has referred to the period following the ravages of disease, when the patient is restored to normal health. This concept accepted the destructive aftermath of disease, often called in surgery "the catabolic phase" of injury (Ch. 12), as inevitable, to be allowed to run its course even though it left the patient weak, wasted, and wobbly. The next step, therefore, was called the period of convalescence, which was often so long that convalescent homes were recommended and, at one time, really needed and proved to be popular. In surgery, it was considered that the effects of operation—even of such relatively simple ones as herniotomy—took a convalescence of three weeks in the hospital, *followed by three weeks at home.*

The contrast with the present attitude is striking, as shown dramatically in the time allotted to convalescence. Instead of six weeks, it is common for patients to leave the hospital in 10 days or even less after a gastrectomy, and to return to work (if they wish) in two weeks. This change has come about for many reasons, basically because it was soon realized that the reparative process could start with the first day of injury, just as the aging process is said to start at birth. This idea of a dynamic equilibrium between injury and repair, catabolism and anabolism, atrophy and growth, has stimulated therapeutic efforts to minimize the former and to improve on the latter, usually at the same time. In this chapter, a few of the factors involved will be discussed, particularly in terms of preoperative preparation and postoperative care. For details the reader is referred to a number of publications specifically devoted to the details of preoperative and postoperative care (1, 2, 3, 4, 5).

PREOPERATIVE PREPARATION

An operation should not be undertaken lightly, nor will it achieve its maximum benefits unless adequate attention is given to preoperative planning, whether the preparation demands days or weeks, or must be completed in minutes or hours. In this section three elements of preparation will be discussed; first, the mental state of the patient, called the *psychogenic factors,* which unfortunately are often neglected. Next and even more important are the *diagnostic requirements,* because these deal not only with the indications and need for operation but also for the evaluation of the risk. Despite the relative safety of operation—thanks to the tremendous advances in anesthesia, including supportive therapy—the surgeon must always reckon with its risk, which is dependent largely upon the physical state of the patient as revealed by the diagnostic data. Third are listed the *specific preoperative procedures,* including particularly the correction of various deficits.

Psychogenic Factors. Often overlooked as unimportant, psychogenic factors may actually play a decisive role in the course of disease (6). The mental state of any patient is inevitably influenced from the very onset of his affliction and is affected favorably or unfavorably by every contact with his physician and, later with other personnel, should he enter the hospital. Once an operation has been definitely decided upon, the importance of psychogenic factors increases, particularly the reaction of the patient to the proposed surgical procedure, his ideas of what it means,

the consequences thereof, and especially the fear of anesthesia. These factors may exert either a favorable or a harmful influence upon convalescence, depending to a considerable extent upon the efforts of the surgeon in charge. To overlook the influence of mind over matter (and vice versa), or to leave it to chance, is to neglect an important part of the clinical picture and to miss significant therapeutic possibilities. Most of the unfavorable psychic influences are based on ignorance, fear, and apprehension, due somewhat to an accumulated background of misinformation, sometimes transmitted by word of mouth, or to misinterpretation of chance remarks overheard after entry into the hospital. Much of the influence of psychogenic factors has to do with the morale of the patient and with boredom, particularly when the surgical disease requires long periods of hospitalization and repeated operations.

An important step in the psychologic preparation of the patient for operation is an unhurried discussion by the surgeon in charge, for he has the opportunity to banish fear and apprehension based upon ignorance. In such an interview, the patient's natural curiosity about his disease should be satisfied, including a discussion of the plans for diagnosis and treatment and the objective to be reached. The time required need not be long, and the details may be few or many, depending upon the individual case and the intelligence of the patient. The surgeon should discuss the diagnosis and prognosis frankly, even when dealing with carcinoma. While surgeons may disagree on this point, the authors feel that, with few exceptions, the diagnosis (and prognosis even if bad) should not be withheld. It is true that many patients become depressed and lose all hope when they learn they have cancer. Because they will learn the truth sooner or later and often with exaggerated prognostic implications, it is far wiser for the surgeon himself to be the source of this information. Such candor not only prevents deception but also actually encourages confidence in his doctor by the patient. It is often not so much that it is the truth, but the manner in which the truth is revealed, that hurts. Hope is the greatest agent we have in the face of serious and ultimately fatal disease, and it should be exploited to the fullest, together with other needed therapy. However, on occasion, it would be unwise to tell the patient he has cancer, because his emotional stability may not be sufficient to tolerate the news. The physician must decide which patients are of this type. The patient may be told he has a growth or tumor which must be or has been removed. Close cooperation by discussion with other members of the family is important under all circumstances and should not be neglected.

A second consideration has to do with courteous and sympathetic care, quiet and restful surroundings, and prompt and efficient attention to a routine, all of which serves, almost at once, to put the patient's mind at rest and to engender a sense of security which constitutes mental rest. Cheerfulness and reassurance on the part of the nursing and intern staff will achieve the same end result. This attitude should be continued during the entire stay of the patient, but it is particularly important just before and after operation. No plan of preoperative preparation can be called adequate unless the patient is free of apprehension, is mentally composed, and has perfect faith in his surgeon as well as in others concerned with his care. Psychogenic factors will prove beneficial rather than harmful if the surgeon in charge evokes the utmost in teamwork by all of those attending the patient.

Psychogenic factors before operation may also play an important part in arriving at a correct diagnosis inasmuch as certain patients may exhibit acute symptoms, particularly abdominal pain, which may be produced by functional disorders such as spasm, rather than acute infection, e.g., appendicitis. It is now well known that a certain type of patient may present symptoms suggesting acute abdominal disease which actually are of psychic origin. Most wise and honest surgeons are able to identify these patients, but in some cases the problem may tax the ingenuity of the most experienced practitioner.

Diagnostic Requirements. The minimum and mandatory diagnostic procedure before any operation in a hospital includes a routine history and physical examination (including blood pressure measurements), a laboratory urinalysis, and a red and white cell count, including a differential. This alone, especially in

emergency operations on patients in previous good health, will tend to avoid unnecessary operations and prevent the tragedy of an ill-advised procedure by the detection of physical defects which may contraindicate it or demand special preparation. When the patient is in poor general condition, the history may reveal the nature of the tissue and fluid deficits, or special blood chemical analyses may be indicated. The influence of psychogenic factors in the diagnosis, as just mentioned, is of obvious significance.

Diagnosis, while the responsibility of the surgeon in charge, is often affected decisively by the intern's routine observations. His history and physical and laboratory examinations may reveal details of significance bearing on the case. Thus an early pregnancy may be detected in a patient about to have an appendectomy for supposed subacute appendicitis. Finding amebas in the stool may contraindicate an immediate laparotomy for an acute surgical condition of the abdomen; the early skin lesion of herpes zoster may be noted in a patient with an erroneous diagnosis of acute cholecystitis; neurological changes may indicate that a gastric (tabetic) crisis rather than a perforated ulcer is the disease present. The intern may likewise detect a sore throat, a furuncle, or other beginning infection near the operative field, each of which may justify postponement of an operation of choice. He may even find evidence of *coexistent disease (see below) including* such lesions as a carcinomatous lump in the breast of which the patient (and her physician) is completely unaware.

Diagnostic procedures are especially decisive in estimating surgical risk and as a guide for the correction of deficits as discussed below. Surgical risk, as revealed by the diagnostic findings, should permit the surgeon to evaluate fairly accurately the *physical state of the patient.* Unfortunately, errors in determination of operability are made too frequently, even by good surgeons. The best operation in the world is no good if it kills the patient. Determination of operability is difficult because there are no mathematical means of determining it. The surgeon must *look for* complications and deficiencies, and weigh their deleterious effects against the operative load planned *for the* patient. Important among these are malnutrition, hepatic insufficiency, cardiac disease, hypertension, and nephritis. Special attention must be given to operations in aged people (6) because the presence of complications or decrements of any type will increase the *expected mortality* rate; in the absence of preoperative and postoperative complications, aged patients will tolerate operations very well. We must treat these complications and deficiencies preoperatively, correcting as many of them as we can. To eliminate or minimize the danger of a fatality, it may be necessary to postpone operation for additional treatment or to modify the type of operation to be carried out. Accordingly, we must increase our efforts to improve the accuracy of our estimation of operability.

Pregnancy, although not classified as a disease, does affect both surgical diagnosis and preoperative preparation. The influence of a coexisting pregnancy on surgical disease of various kinds is discussed in other parts of the text.

Special Preoperative Procedures. Preoperative procedures may be simple or complicated, depending somewhat upon the urgency and the risk of the operation, as discussed above. In the following discussion, three groups of preparatory measures and one transition stage are considered, not in great detail inasmuch as further information can be found in other sources already mentioned.

1. *Special procedures* depend upon the type of operation to be carried out and will be treated in the discussion of the regions involved. For example, gastric lavage is essential before gastric resection whenever there has been excessive gastric retention due to pyloric obstruction. This permits edema and inflammation of the stomach walls to subside. Cleansing enemas are necessary before operation on the colon. Refrigeration of a gangrenous infected extremity associated with severe systemic signs of toxemia, especially in the presence of diabetes, will greatly reduce the mortality due to amputation. These special procedures are carried out while various nutritional and other deficits are being corrected.

2. *Correction of deficits,* when present, plays a decisive part in the preparation for operation of any magnitude and will, in itself,

greatly reduce surgical risk. The patient in poor general condition due to a readily remediable surgical lesion—such as a stenosing duodenal ulcer or carcinoma of the stomach or colon—can now be made relatively safe for even extensive operation by adequate correction of deficits. The details of therapy, however, must be based upon a fairly accurate estimate of the patient's previous losses and his present nutritional status. This can usually be determined on the basis of a good nutritional history, physical examination, and simple laboratory measurements. These deficits should be visualized in terms of the loss of specific body constituents which, biochemically, means protein, water, electrolyte, and vitamins, as discussed previously (p. 161). Of primary importance is the correction of water and electrolyte deficits in the dehydrated patient as discussed in detail in Chapter 9. Transfusions may also be indicated, but only after careful evaluation of the findings, including even accurate blood volume measurements. Complete restoration of all nutritional deficits is seldom possible within the time available, but as many as possible should be corrected.

The time factor is often overlooked in the plan for the correction of deficits. This depends upon the urgency of operation. While it is, of course, obvious that the risk can be greatly reduced by correcting existing deficits, operation sometimes must be carried out in the face of such deficits. For example, the patient may have profuse bleeding within the abdominal cavity that cannot be stopped or does not stop and which has led to continuing shock not responsive to adequate transfusions. In such a case, operation, even though the patient is desperately ill and in shock, offers the only hope of removing the cause of the hemorrhage and thus of giving the patient at least some chance of recovering from an otherwise fatal condition. Another example is the patient with a strangulated intestinal obstruction who cannot be brought into condition for operation by any method and, therefore, requires an exploration for the removal of the lesion which is, in itself, the cause of severe prostration and even shock.

Less urgent operations as, for example, for perforation of an acute appendix, justify a delay of at least several hours for the correction of dehydration and for adequate chemotherapeutic coverage. In other cases, the deficit is less acute or the operation less urgent, permitting many days of preparation which are not only indicated but even necessary to insure a favorable outcome.

3. *Routine preoperative orders* depend on the type of operation and anesthetic, but, in general, they include the following: Soporific drugs such as barbiturates, by mouth, are often used to ensure a good rest the night before operation. An enema is usually given before operation, since the bowels are generally inactive for several days afterwards. Preoperative *catharsis is to be condemned* as a routine because it is apt to increase postoperative nausea, gas pains, vomiting, and distention. However, in colon surgery, mild catharsis to empty the large bowel is used by some surgeons, although the authors oppose it. The field of operation must be adequately prepared by careful shaving and cleansing of the skin over a wide area surrounding the proposed incision. Detergents are useful aids in surface sterilization in operations on the hands or feet. The skin may be prepared for operation with different methods and solutions. A common method utilizes soap, water, and alcohol, but this should not be used in patients with palpable malignant tumors, because of the danger of spreading the tumor by the scrubbing process. Many surgeons use antiseptic agents alone; many are available. Preanesthetic medication is discussed in the chapter on anesthesia.

4. The *transition* from preoperative preparation to postoperative care involves two periods in the experience of the surgical patient: (1) the *operation*, including the anesthetic; (2) the *recovery room*, adjacent to the operating room, for the initial stage of recovery following operation. The importance of a recovery room is now a matter of general agreement, and the benefits have been established without question. The recovery room affords special care for the patient during the early postoperative period which is, of course, of special significance in those receiving a general anesthetic. This period includes the time required for full recovery of vital signs and normal consciousness. Ordinarily this period lasts only a few hours, al-

though in many hospitals the recovery room is designed to care for the patient for a day or two, and thus assumes some of the responsibility ordinarily called *postoperative care.* A thorough discussion of the recovery room will be found in the monograph by Sadove (7).

POSTOPERATIVE CARE

General Considerations. The systemic reaction to operation and anesthesia profoundly affects the character and therapeutic requirements of convalescence (8, 9, 10). All organs and probably all cells are involved in this response, and the load imposed upon systems whose function is already borderline may precipitate overt failure by pulmonary insufficiency, adrenocortical insufficiency, cardiac decompensation, renal failure, hepatic coma, and numerous other complications. Moreover, even if the functional reserve of all organs is normal, the altered activity occasioned by the stress will influence the postoperative treatment. For example, it is usually poor judgment to force oral intake immediately following surgery, when motor and secretory functions of the bowel are altered; the food frequently will be regurgitated by the temporarily indisposed digestive tract. Similarly, extensive hormonal alterations occur after operation which, collectively, impair the capacity of the kidneys to excrete water. Thus, whereas the intravenous infusion of large volumes of fluids not containing electrolytes usually is not hazardous in the normal subject, such an infusion in the postoperative patient may produce water intoxication. Other examples could be cited. The point is that the early stage of convalescence represents a special circumstance which calls for special precautions.

The traditional attitude toward postoperative and post-traumatic care has been one of careful observation for the detection and avoidance of accidents and of symptomatic treatment of clinical manifestations as they arise. Aside from this, no active program has been considered necessary, great reliance being placed upon the natural reparative processes of the body, as discussed above. Nevertheless, instead of depending upon the spontaneous efforts of nature, positive methods of therapy are now employed because they shorten the period of convalescence and reduce many of the complications formerly thought inevitable.

That reparative processes may begin almost immediately following injury is now an acknowledged fact, which means that their beneficial effects may be synchronous with, rather than subsequent to, the effects of injury.

Basic Routine Orders for the Immediate Postoperative Period. Certain general orders are essential following all types of major surgery, regardless of what other orders may be required for special circumstances. These basic orders are:

1. Keep running record of the vital signs. The blood pressure, respiration, and pulse rate should be checked at stated intervals. Measurements should be frequent (every 15 to 30 minutes) until the circulation has stabilized and until the patient is awake.
2. Give nothing by mouth.
3. Record administration intravenous fluids (8).
   a. Finish blood transfusion?
   b. How much, of what type fluid, how fast?
4. Give sedative or analgesic.
5. Note and record early ambulation, diet after patient has passed stage of nausea, antibiotics if to be used, deep-breathing and other exercises in bed, and procedure in case patient does not void within 12 or 14 hours after operation.

The request for frequent rechecks of vital signs ensures that the patient will be seen often—the most reliable means of detecting, at an early stage, still such other complications as external hemorrhage, respiratory obstruction, or prolonged unconsciousness. After the patient is fully alert and his cardiopulmonary apparatus has stabilized, the postoperative hazards rapidly diminish in number and magnitude.

Postoperative Activity and Ambulation. Although immobilization and rest in bed are definitely necessary after operation, it is becoming increasingly apparent that complete immobility in any position is harmful. For example, bed rest and immobilization are known to increase the likelihood of pulmonary and circulatory accidents, to produce atrophy of disuse, and to lead to disturbances in neuromuscular abilities (often called "de-

conditioning") and to certain poorly understood metabolic changes that include calcium mobilization with the risk of kidney stones. Aside from these harmful effects, there are such subjective difficulties as the need for defecation and urination in the horizontal position. Vital capacity of the lungs is known to be impaired also during immobility and rest in bed. Of perhaps still more importance, is the fact that while a patient is at bed rest he is in negative nitrogen balance.

Some confusion has arisen regarding the emphasis on physical factors, especially early ambulation, after operation. These factors should be clarified. In the first place, early ambulation is often taken to mean merely the termination of bed rest, which does give the patient, in many instances, a psychological lift because it means to him the first step in recovery. However, termination of bed rest in itself means very little unless it includes movement of the lower extremities by walking. The patient who merely gets out of bed and sits in a chair may be worse off in terms of promoting blood flow through the lower extremities than if he were lying in bed with the legs elevated. Finally, the beneficial effects of movement in combating the atrophy of disuse and in promoting the circulation of the lower extremities may actually be achieved while the patient is still confined to bed. This is done by instituting a definite program of muscular exercises from the very beginning (see below).

First, the cooperation of the patient is obviously essential and can nearly always be obtained if he understands the details and objectives of the program. This requires a preliminary discussion of such plans, preferably with the family as well as with the patient. Second, the influence of example in any program is always beneficial. Many patients will cooperate much more readily when they are able to see other patients doing the same thing, particularly when the benefits of such action and the absence of danger are apparent. Third, the specific orders must be individualized, based upon the type of operation and the patient. Fourth, the program should start as early as possible, indeed, as soon as the patient awakens from the anesthetic, or in other instances, as soon as he is returned to his bed.

Two general *types of early movement* are nearly always indicated and have few, if any, contraindications. *First, breathing exercises* are started in order to maintain a good interchange of air with all parts of the lungs. This objective may be achieved by ordinary, voluntary deep inspirations for several minutes every hour, preferably in the sitting position, which always increases the vital capacity of the lungs. In patients with actual or suspected patchy atelectasis, deep inspiration and forced expiration are increased by urging the patient to cough while sitting on the edge of the bed with the abdominal and lower costal margin held firmly with a tight binder or by the hands of the doctor or nurse. Such exercises and procedures often aid in clearing the finer bronchioles and, if carried out early, will prevent many postoperative pneumonic complications. The importance of adequate pulmonary ventilation has been emphasized by Dripps and Deming (11), and by Brattstrom (12). *Second, a program of calisthenics* for the upper and lower extremities should be started immediately after operation for 5 or 10 minutes every hour while the patient is awake. This is continued in most cases where bed rest is necessary. Early termination of bed rest, within 24 hours, is usually indicated in nearly all surgical patients after operation unless definitely contraindicated, as discussed below, or opposed by the patient. The first step in early ambulation should be supervised by the surgeon in charge and is preceded by short periods during which the patient sits up in bed with his feet resting on a chair. Once the patient is able to walk, and this is often possible within 24 hours, even after extensive abdominal operations, increasing activity is continued.

The *contraindications* to ambulation are numerous. Severe infection, regardless of its location, is a strong contraindication; so also is high fever, regardless of its cause. Patients who are extremely weak should not be ambulated until improvement in nutrition is attained and exercises in bed have shown some beneficial effect. Cardiac decompensation, recent coronary thrombosis, and pulmonary complications of any significance are obvious contraindications. If, for some reason, an abdominal incision has been closed insecurely, it is usually unwise to get the patient

out of bed for several days, because of the danger of wound disruption.

NUTRITIONAL FACTORS. Starvation following operation and injury has, in the past, been accepted as inevitable or even necessary as part of the effects of injury. The present trend, however, is to combat starvation, beginning immediately after the injury or operation, by proper attention to the nutritional requirements of the surgical patient (see p. 165). Postoperative nutritional care is based upon (*a*) the correction of deficits as they occur, and (*b*) the prevention of deficits which might occur. The former category includes the restoration of losses sustained during operation or after operation, by the adequate administration of whole blood, plasma, water, and electrolyte, as discussed in the previous chapter. The latter category includes the prevention of starvation after operation by the maintenance of a food intake of all the necessary elements in the diet. This is now possible whether the patient is able to eat or not. If he is unable to eat, reliance upon injections of glucose solutions alone, as in the past, will inevitably lead to protein starvation. The inclusion of protein nourishment as amino acid mixtures will prevent, to a great extent, the protein starvation which was inevitable in the past. The addition of vitamins, especially vitamin C, to such a parenteral diet is often of equal importance.

Parenteral alimentation, when indicated, is always temporary, to be terminated as soon as oral intake can be resumed. Indeed, oral intake can usually be resumed earlier if the parenteral diet contains protein, for reasons discussed elsewhere. An adequate dietary intake must therefore be maintained by constant attention to details. Moreover, in those patients who do not require parenteral injections, the same general principle of avoiding protein and vitamin starvation applies from the very beginning. If the patient is unable to take a full, well-balanced diet, it is necessary to give priority to protein and vitamins, inasmuch as wastage of these elements in the body is likely to lead to physiologic impairment. Calories are also essential but may, to a considerable extent, be obtained from adipose tissue which is actually designed to serve this purpose. As a general rule, therefore, the adult patient of average weight should receive, in addition to vitamins, at least 100 gm. of carbohydrate and about 100 gm. of protein as the *minimum* daily requirement until he is able to take a full complement of food.

Postoperative Complications (13). The number and types of complications which may develop after operation are so great that space will permit discussion of only a few of the more important ones.

Beginning immediately after operation, and continuous with the anesthesia chart, are recorded frequent and careful observations of the pulse, respiration, and, in certain instances, repeated blood counts and blood pressure determinations, as noted above. The basic aim is to note early evidence of complications and to ensure their prompt detection and treatment. This objective depends, to a great extent, upon an ever-watchful and alert resident and nursing staff. For example, the first evidence of shock may be an increase in pulse rate. Pneumonia may be suggested quite early by an increased respiratory rate, tracheal obstruction, or restlessness.

Avoiding complications is, of course, a primary objective and, indeed, is frequently achieved, as shown by a prompt return of normal function without significant symptoms even after extensive operations. In the following discussion, only a few complications will be mentioned for they are described in more detail elsewhere in the text. Most of the untoward symptoms are considered, even though many of them are almost "normal," since they occur frequently and soon disappear. Nevertheless, a good postoperative program should aim to prevent them, and, if they occur, to treat them effectively, especially to see that they are not the harbingers of complications. It should be emphasized, however, that many postoperative manifestations are due to the nonspecific systemic and outlying effects of injury, as discussed in detail in Chapter 12.

1. *Pain* is probably one of earliest and and most frequent postoperative complaints, although it may be completely absent. Investigation as to the nature and cause of pain should precede medication. As pointed out by the studies of Beecher (14), anxiety plays an important part in the subjective complaint of wound pain in military and civilian sur-

gery. Simple sedation and attention to psychogenic factors discussed above are often sufficient to produce relief. Morphine is the most efficient drug for the relief of pain, yet, because of its depressive effect on respiration and its tendency to prolong anorexia, it should not be used if other means are effective. Moreover it *should not be ordered as a routine*. The maximum effect on relief of pain itself is usually reached with a moderate dose, e.g., 15 mg. or 0.25 grains; increasing the dose increases its depressant effect without significantly increasing the degree of analgesia. Delay in giving analgesic drugs decreases their effectiveness. A small dose early will do more than a large dose later. Individual variations are frequent. Intravenous injection is the most rapidly effective.

Abdominal pain is obviously most likely after abdominal operations. Most commonly located in the incision, it is due largely to the pressure of skin sutures, particularly when they have been tied tightly. Subcuticular sutures are less likely to be followed by pain. However, this type of pain generally disappears within 24 hours. In many cases, abdominal pain will be relieved by such simple measures as change of position or loosening of tight dressings. When the pain is cramplike and more deeply seated, it is often due to increased peristalsis called "gas pains," particularly when associated with some abdominal distension. Such pain is usually due to air aspirated or sucked into the stomach during or after anesthesia and then passed into the intestines. The origin of gastrointestinal gas in this way has been well studied by several observers, especially by Maddock and associates (15). It can be prevented by manual evacuation of the stomach by the surgeon before closure of the abdomen and by efficient gastric aspiration (Wangensteen) during and after anesthesia, until the patient regains consciousness. When gas pains occur later they will usually yield to such procedures as gastric lavage, the use of a rectal tube, or a small enema. Intestinal obstruction should be suspected if pain is persistent.

2. *Nausea and vomiting*, although frequently absent, may be the most distressing of postoperative symptoms and are not limited to abdominal operations. The anesthetic agent may be the cause; in abdominal operations, the peritoneal trauma, or aspirated air (see above), especially when associated with distension, may be the causative factor. In sensitive patients, the problem may be an especially difficult one. Reassurance and nursing care are particularly effective. Gastric lavage may be necessary, particularly when there is evidence of much gastric retention. A period of 24 hours or more during which nothing by mouth is given and parenteral feeding maintained is advisable before starting oral administration of fluids. However, such simple fluids as water, tea, or unsweetened carbonated beverages can be allowed, if requested. Reassurance, sympathy, and psychotherapy, which should be included under the heading of bedside care, are of extreme importance. They sometimes spell the difference between a rapid and a prolonged convalescence. Patients allowed out of bed early are less apt to suffer nausea and vomiting than those kept in the horizontal position.

When vomiting results in the loss of considerable fluid, dehydration of the blood and tissues inevitably occurs and this, in itself, may provoke further nausea and vomiting. Such dehydration will require correction, with sufficient parenteral fluid to replace the loss, the details of which have already been discussed. An accurate record of intake and output is useful in estimating the degree and correction of dehydration.

If nausea and vomiting continue for several days after adequate therapy, the existence of such a serious complication as intestinal obstruction, general peritonitis, enteritis, wound disruption, and, particularly, *acute dilatation of the stomach* should be suspected. The latter is accompanied not so much by pain as by distention and repeated regurgitation of small amounts of fluid. It is really a neurogenic disorder and is often secondary to retroperitoneal hemorrhage or spinal or pelvic fractures. Treatment is specific and consists of evacuation of the stomach through a nasal catheter or a stomach tube as frequently as necessary. An indwelling tube—as initially recommended and popularized by Wangensteen, provided with continuous mild suction, and inserted at the time of operation—will effectively prevent dilatation of the stomach and is widely used as a routine procedure after intraabdominal operations. Such gastric

decompression may be continued for several days to prevent gastric retention and dilatation, and then used as a guide in determining when the oral administration of fluids and food is safe. This is done by clamping the tube at intervals and observing the behavior of ingested fluids. If no retention occurs and gastric emptying is prompt, the tube is removed and an increasing diet started.

3. *Insomnia* is frequently serious enough to require specific attention. Good nursing, absence of noise and excitement, and elimination of disturbing psychogenic factors, as already discussed, are obviously important. Relief of pain is axiomatic. Pharmacologic means must sometimes be used; the barbiturates by mouth or chloral hydrate or paraldehyde by rectum are usually quite effective, provided an adequate dose is employed. Up to 1 gm. (15 grains) of chloral hydrate is safe and may be necessary to achieve sufficient sedation. Codeine in conjunction with a barbiturate is often more effective than either alone even when used in small doses, e.g., 30 mg. and 60 mg. respectively. Morphine may be used as a last resort but is very seldom justified or necessary in the absence of severe pain.

4. *Failure to urinate* may be due to urinary retention, as already discussed. However, oliguria or anuria must always be suspected, particularly when there is no pain or distention and when bladder dullness is absent. A diagnosis requires catheterization. The cause of anuria may be actual disease of the kidney, functional or organic obstruction to the ureters, or transient suppression of secretion from dehydration. Differential diagnosis is important for renal impairment (lower nephron nephrosis) is aggravated by giving large volumes of fluid whereas dehydration requires such therapy. Renal insufficiency calls for limiting the fluid intake to insensible losses which normally are not over 1,000 ml. per day, i.e., 1 liter of 10 per cent glucose in water. In any case, renal complications present a difficult therapeutic problem, including the removal of such causes as damaged tissue in extensive wounds (16).

5. *Pulmonary complications*, though now fairly rare thanks to better anesthesia and to prophylactic chemotherapy, are still a hazard (17). Aspiration pneumonia is still too frequent (18) and is due to actual aspiration of regurgitated gastric contents into the lungs immediately after operation. The terminal changes are described in the excellent postmortem studies of Irons and Apfelbach (19). Aspiration pneumonia should be minimized or completely prevented by adequate gastric lavage before, during, and after operation whenever considerable gastric retention is present. Expert anesthesia and the increasing use of the recovery room have reduced this hazard considerably. Pulmonary edema caused by excessive transfusion of blood or by too much fluid (especially if more saline than indicated) is also becoming more uncommon. Since it is iatrogenic, such a complication is really inexcusable.

Postoperative pulmonary complications depend, in general, upon the length and type of operation, increasing age, recent upper respiratory infections, expertness of anesthesia, and gentleness of the surgeon. Upper abdominal procedures are especially likely to provoke pulmonary complications. Recognition is based upon the development of rapid respiration, fever, thoracic pain, dyspnea, cyanosis, and cough. When atelectasis is massive, i.e., involving an entire lobe, such characteristic physical signs as hyperpnea, absence of breath sounds over the affected area, and a shift of the mediastinum to the involved side are present and diagnostic. Pulmonary embolism is usually manifested by sudden thoracic pain, respiratory and circulatory impairment, and expectoration of blood-tinged sputum, occasionally by shock alone. Roentgenography may be very helpful for differentiating the various lesions, but a portable apparatus should be employed for the very ill patient.

The early use of pulmonary exercises, as already mentioned, and prophylactic chemotherapy, where indicated, will also tend to prevent many cases of patchy atelectasis and probably other types of pulmonary involvement. Once a definite pulmonary complication is present, treatment is largely medical and in nearly all cases calls for the intensive use of chemotherapy, based if possible on identifying the organisms and determining their sensitivity to various agents. In massive atelectasis, evacuation of a bronchial plug is specific and often dramatically effective; it

can sometimes be induced by rolling the patient from side to side and supporting the abdominal wall while the patient coughs. Aspiration of the bronchi by means of a catheter passed through the glottis is also effective. Bronchoscopic removal of the obstructing plug may be indicated if simpler measures fail to promote aeration. Oxygen therapy is useful, particularly when it is started early. In pulmonary embolism, papaverine (grains ½) and atropine (grains $\frac{1}{150}$), have been found to be of value by de Takats and Jesser (20). Anticoagulant therapy, starting with intravenous heparin, is usually indicated.

Aerosol therapy is a useful adjunct in many pulmonary conditions and may be helpful in postoperative atelectasis. In atelectasis, the dried, thickened mucus blocking the bronchioles and the smaller bronchi is often extremely tenacious and difficult to expel. Such detergent wetting agents as superinone (alevaire) or tergemist tend to overcome this difficulty by liquefying these thickened secretions. Special nebulizers are provided with oxygen or air so that the agent is *inhaled by the patient* in the form of an aerosol (fog). Aerosol therapy has also proved helpful early after tracheotomy. These wetting agents, in addition to liquefying secretions, serve to humidify the dry anhydrous oxygen being given patients. Aerosol therapy is also useful in the intrabronchial administration of such antibiotics as penicillin, of such bronchodilators as isoprel or epinephrine, and of certain enzymes as tryptar, which also aids in liquefying tenacious secretions. However, these agents are often of little or no value.

6. *Surgical shock* is discussed in a separate chapter. When it occurs following operation, more or less the same clinical manifestations develop as after any other trauma, except for the masking influence of the anesthetic. General anesthesics affect the sensorium, and thus make it difficult to judge the degree of cerebral anoxia. Knowledge of the operative procedure, however, helps in estimating the likelihood of internal hemorrhage, which, if severe, may necessitate a second operation to control the bleeding. Treatment is described in the chapter devoted to shock.

7. Surgical shock may be mistaken for *cardiac failure,* a fortunately rare postoperative event, which is manifested by dyspnea, cyanosis, and, later, by evidence of pulmonary edema. The circulatory impairment is evident by the appearance of a fast and often irregular pulse. In cardiac failure, the intravenous injection of a large volume of fluids is obviously contraindicated and may provoke an immediate fatality. Indeed, venesection or venous tourniquets may sometimes be indicated rather than intravenous injections. Oxygen therapy by inhalation, preferably under positive pressure, is perhaps the most important feature in treatment. Appropriate supportive cardiac therapy should be given as indicated in the individual circumstances. The use of hexamethonium may diminish the central blood volume.

8. *Fat embolism* is a rare postoperative and post-traumatic complication and is associated with a high mortality. It was originally thought to be due to the entrance of fat into the blood from the traumatized bone marrow. Lehman and Moore (21), however, presented evidence that the fat in the blood is indigenous, being formed by a change in the physical character of the blood lipoids. Symptoms are of two types, one circulatory, the other pulmonary. Ophthalmoscopic examination may show retinal vessels filled with fat. A diagnosis can sometimes be made by finding fat in the sputum or urine (Warren, 22). Treatment is that of shock and pulmonary complications in general. *Air embolism* is usually serious only after operations involving the pleural cavity, because of the access of air into the pulmonary vein which carries it to the left heart and thence to the brain, thereby producing signs of cerebral embolism.

9. Unfortunately *thromboembolic disease* is still a fairly common and serious postoperative complication. Pulmonary embolism rarely follows thrombophlebitis femoris (phlegmasia alba dolens, milk leg), but occurs with a type of thrombosis first described by Payr in 1930 and by Homans (23) in 1934 as a "thrombosis of the deep veins of the lower leg," in which a long clot attached only at one distal point, usually the plantar veins of the foot, extends proximally, floating freely in the blood stream and easily detached to form a large embolus. The term phlebothrombosis was later applied to this

lesion by Ochsner and DeBakey (24). Such a clot forms because of (*a*) slowing of venous blood flow; (*b*) changes in the blood, producing more rapid coagulation; and (*c*) endothelial injury. Based on these causes, prevention as the most effective form of therapy could be achieved readily by (*a*) increasing venous return from the legs by early postoperative movement and muscular exercise of the feet, (*b*) the use of anticoagulants, and (*c*) prevention of injury to the veins of the leg, respectively. Of these methods, the first is clearly the most physiologic. Once a deep thrombosis has started, movement is probably harmful by aiding in its dislodgement, whereas anticoagulant therapy should halt its propagation and reduce the likelihood of embolism. Early exploration of the vein proximal to the thrombosis, removal of the clot, and ligation of the vein was recommended (Homans) years ago, but is seldom carried out now. The clinical detection of phlebothrombosis may be difficult, but the earliest sign is deep tenderness in, and on dorsiflexion of, the foot. Injury to the plantar fascia, however, may produce the same signs. Fatal pulmonary embolism is by no means limited to surgery; it is still seen in medical and obstetrical cases (25). It is much less common in young patients than in elderly patients; accordingly, more active prophylactic therapy is indicated in the latter group. A thorough and critical review of postoperative thromboembolic disease has been reported by DeBakey (27).

10. *Infection* of an operative wound may be serious, especially in large incisions. Such infections are often ushered in by an unexplained increase in the temperature, an increased local tenderness, and redness or swelling of the wound, but in some cases may be present silently. Further details will be found in Chapter 14.

11. *Postoperative fever* may be self-limited and due merely to the effects of absorption of damaged tissue, especially of hemoglobin. When fever is high or persistent, another cause must be sought. The most common are pulmonary, urinary, or wound infections. Occasionally it is due to chemotherapy.

12. *Wound disruption* (*dehiscence*) is still too frequent, especially after anterior abdominal incisions, and traditionally is supposed to be due to persistent coughing or retching, which undoubtedly plays an important role in some cases. Nutritional deficits, especially in protein and in vitamin C, are also responsible in some measure. More often, however, the fault lies in such imperfect technic during closure as sutures tied too tightly, the use of continuous rather than interrupted sutures, and the inclusion of insufficient fascia in the suture.

The first indication of complete wound disruption may be the sudden appearance of excessive serous discharge on the dressing. To an inexperienced surgical intern the sight of coils of intestine after removal of the dressing is a memorable experience. However, it is not as serious as might be expected. A high mortality rate is associated with this complication, primarily because it often occurs in patients who are seriously ill; it is particularly common in elderly patients with cancer or jaundice. Peritonitis or herniation can usually be avoided if the wound is promptly closed. This must be done under local or general anesthesia. Many closely placed, through-and-through sutures are used, each of which includes all layers of the abdominal wall.

More commonly, disruption of the wound is incomplete and is limited to the deeper layers of the incision which may produce some of the manifestations of intestinal obstruction (particularly nausea, vomiting, and distention) and lead eventually to the formation of a ventral hernia.

13. *Fecal impaction* is a fairly common postoperative complication in elderly patients. It is readily diagnosed by rectal examination, but will be overlooked unless such an examination is made. A fecal impaction will not necessarily result in absence of bowel movements; many of these patients indeed have frequent, but small, liquid stools. Considerable rectal pain and tenesmus may be present, particularly at each attempt to move the bowels. A severe grade of fecal impaction may be associated with so much abdominal pain and distension that a diagnosis of intestinal obstruction may be made. These manifestations are so readily relieved by removal of the impaction that a rectal examination should not be delayed whenever the condition is suspected. An oil enema, followed

in several hours by a soapsuds enema, is occasionally effective in softening and expelling the fecal mass, but when the impaction is hard, as is usually the case, the mass *should be broken up by digital manipulation.*

The use of enemas to promote early bowel movements was popular years ago, but no longer is. With diminished food intake there is no need for an early bowel movement; besides, with early ambulation a spontaneous evacuation usually occurs after three or four days.

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11

ANESTHESIA

The great progress made in anesthesiology during the past two or three decades has been due to the fact that the modern anesthesiologist is also trained in various basic sciences including pharmacology, physiology, and biochemistry. This additional knowledge has made it possible to understand better the effects of the various anesthetic agents and to extend the frontiers of anesthesiology. This expansion of anesthesiology has stimulated the surgeon to enlarge the scope of surgery and has made possible the rapid progress made in thoracic and cardiac operations (1, 2, 3, 4).

No anesthetic is ideal; the advantages and disadvantages of the various agents can best be appreciated by close cooperation between the surgeon and the anesthetist. An attempt should be made to choose the anesthetic or combination of anesthetic agents best suited for the patient. Since anesthesiology has become a specialty of its own, only the general principles will be discussed here.

Analgesia implies loss of sensation to pain without loss of consciousness. *Anesthesia* implies loss of all sensations.

GENERAL ANESTHESIA

General anesthesia may be administered by several different routes: 1. inhalation; 2. intravenous; and 3. rectal. The anesthetic agents are carried to the central nervous system before anesthesia is produced.

In addition to causing loss of sensation, anesthetic agents possess the power of eliminating motor nerve impulses, which results in more or less complete muscular relaxation. This property is possessed by the agents in varying degrees and determines, in part, the choice of anesthetic, depending on the degree of muscular relaxation required for a particular operation. Different parts of the central nervous system are affected by different concentrations of the various anesthetic agents; the medulla is relatively resistant. This makes it possible to produce safe levels of anesthesia without undue depression of vital centers.

Preanesthetic Medication. Legitimately regarded as part of the anesthetic procedure is the administration of preanesthetic drugs, which are of two major types. One group, including morphine, meperidine (demerol), and pentobarbital (nembutal), acts as a sedative, minimizing apprehension, and thus reduces the amount of anesthetic agent required for induction; this results in a smoother anesthesia. The other type comprises the belladonna drugs, primarily atropine and scopolamine. Atropine will minimize pharyngeal secretions, reducing the tendency to obstruction and aspiration into the lungs. Similarly, scopolamine will dry secretions and has the advantage over atropine in that it also produces some psychic sedation and amnesia. The dosage of these drugs should be carefully individualized. The aged require much less sedation than young adults; factors which alter the metabolic rate will correspondingly increase or decrease the dosage required. Sthenia, fever, pain, excitement, and hyperthyroidism will increase the amount of premedication required. The anesthetic agent to be used and the degree of relaxation to be achieved also modify the dosage. Nitrous

oxide and ethylene call for heavy sedation, ether for moderate sedation, and cyclopropane for very light sedation to avoid respiratory depression. Paradoxically, the deeper the anesthesia required, the lighter should be the preliminary sedation because heavy sedation causes respiratory depression, which may lead to hypoxia, and slows or prevents the administration of enough inhalation agent to produce deep anesthesia.

Stages of General Anesthesia. General anesthesia is divided into four stages. The first is the stage of *analgesia* in which there is a progressive loss of sensation but not of consciousness. The second is the stage of *excitement* during which the patient, though already unconscious, tends to exhibit a hyperactivity which occasionally requires forcible restraint. The third is the stage of *surgical anesthesia* during which operations may be carried out. There may be certain reflex responses to stimuli, but these diminish and relaxation increases as anesthesia deepens. The fourth stage is that of complete *respiratory paralysis.*

Signs of Anesthesia. *Sensory* perception disappears early although stimuli which ordinarily give rise to pain may give rise to a reflex action in the early stages of anesthesia. During the *first stage* of anesthesia, motor power is retained although it may be purposeless. During the *second stage,* voluntary control of movement is lost, but reflex responses are maintained; in fact, they may be violent. During the *third stage,* response to sensory stimulation is lost and the tone becomes weaker. This stage is divided into four planes. Entry into the first plane is indicated by loss of the eyelid reflex; into the second plane by cessation of eyeball movement; into the third plane by beginning intercostal paralysis; and into the fourth plane by complete intercostal paralysis, breathing being entirely diaphragmatic. In the *fourth stage* there is complete motor relaxation and respiratory paralysis; it is therefore dangerous.

Respirations undergo several changes as the anesthesia deepens. During the first stage, breathing is under voluntary control although the patient may hold his breath or breathe rapidly. During the second stage, breathing becomes irregular. As the patient enters the third stage, it becomes regular and automatic; inspiration and expiration are equal in duration and amplitude. As anesthesia deepens, inspiration becomes shorter and gasping while expiration lengthens, is less forceful, and is followed by a gradually lengthening pause, until all respiratory effort ceases.

Eye signs are slightly helpful in determining the depth of anesthesia. During the first stage, the eyelids and eyeballs move in a reflex and voluntary manner. During the second stage, the lids are rigid and light-reflex active. As the patient enters the third stage, the eyelid reflex is lost and voluntary movements cease. In the second, third, and fourth planes of the third stage the eyeballs are fixed, looking straight forward. In the fourth plane, the pupils dilate and light reflex is lost.

Circulatory signs are very important in determining the stage of anesthesia, and, of more importance, they give an indication as to the physiologic status of the patient. If bleeding is uncontrolled or if blood loss is not replaced by adequate transfusion, the *blood pressure* falls. It also falls if the anesthesia becomes too deep. It may rise or fall as a reaction to numerous other factors such as hypoxia, hypercarbia, and reflex stimuli. On many occasions, the exact cause is not apparent, but the deviation from normal is an indication that a pathologic condition has developed; the anesthesiologist must find the cause and correct it as soon as possible. The *pulse* varies greatly depending upon numerous factors including those mentioned above. A change in quality or rhythm may be indicative of myocardial failure. The anesthesiologist must know the pulse rate at all times to obtain the very earliest indication of cardiac distress, particularly since *cardiac arrest* is such a serious complication requiring immediate corrective treatment (within four minutes of onset). The color of the skin is very important. Cyanosis is an index of reduced hemoglobin in the blood, related to oxygen deficiency, but lack of oxygen may be present long before the development of cyanosis. *Pallor* indicates vasoconstriction and may be an early sign of shock even before hypotension. *Capillary tone* is depressed by deep anesthesia and shock and can be measured in the nail bed by the capillary refilling time, i.e., the time required for the return of color after blanching by pressure.

Recovery from Anesthesia. The immediate postoperative period is of special importance inasmuch as several hours may elapse before consciousness is regained, particularly if ether has been given. Aspiration of vomitus is one of the greatest dangers in the recovery period and may occur despite an indwelling gastric catheter. For this reason, it is essential to have the patient on his side during the recovery phase. Vomiting is perhaps more common following ether, but any anesthetic may produce nausea and vomiting. It is true, however, that aspiration of vomitus is less likely following a gas anesthetic because the patient may have recovered sufficiently within 5 or 10 minutes following cessation of administration of the anesthetic to prevent it. Another important danger in the recovery period is obstruction of the airway, which is usually caused by the tongue falling back against the pharynx or by laryngeal spasm. Audible stridor will be noted; if the obstruction is severe or persistent, cyanosis and the serious effects of anoxia will develop. It may be necessary for a nurse or physician to hold the angle of the jaw forward to maintain an open airway; however, a metal or rubber "airway" usually will hold the tongue forward and relieve the obstruction. While the patient is unconscious, the lateral position is preferable. The patient recovering from an anesthetic should be covered with no more blankets than a conscious patient even though he is in shock. Experience during the past several years indicates that assignment of newly operated patients to a recovery ward for 2 to 24 hours will save many lives because of better facilities and care by nurses who are specially trained in complications occurring in the immediate postoperative period.

Hypotension during recovery from an anesthetic is not unusual and may be due to innumerable causes. Important among these causes are hemorrhage, change in position (e.g., lithotomy to horizontal), change from high to low oxygen or carbon dioxide content of the inspired gases or air, cardiac disease, pain, excessive narcosis, and transfusion reaction. Details may be found in a publication by Barbour and Little (5). This complication is a serious one demanding accurate and early diagnosis because persistence of a low blood pressure may lead to oliguria and cerebral damage and because treatment is so varied. Perhaps the most important cause demanding most urgent therapy is hemorrhage. If the hemorrhage is internal, its detection may be difficult unless accurate determinations of blood volume are available because changes in hematocrit or hemoglobin levels are delayed for hours. Regardless of the cause, postoperative hemorrhage must be stopped promptly; since it is commonly internal, from one of the body cavities, the patient usually must be taken back to the operating room. Regardless of the cause of the hypotension, administration of a vasopressin may be indicated to prevent serious sequelae such as oliguria and cerebral damage. Of the vasopressins available, levarterenol bitartrate (Levophed) and phenylephrine hydrochloride (neo-synephrine hydrochloride) are most commonly used. If used, they should not be mixed with whole blood or plasma but should be given in physiologic saline or in 5 per cent glucose solution. If levarterenol bitartrate is used, 4 ml. of a 0.2 per cent solution is placed in 1,000 ml. of saline or glucose solution, and this solution is allowed to go in slowly at first (one drop every 5 or 10 seconds). If phenylephrine hydrochloride is used, 1 or 2 ml. of a 1 per cent solution is put into a liter of fluid. A blood pressure cuff must be kept in position and readings taken every few minutes. As the blood pressure recovers, the intravenous administration is discontinued.

The Airway. Of primary importance in giving any anesthetic is the patency of the air passages. After relaxation occurs, the tongue tends to drop back, and, aided by the accumulation of mucus, a partial obstruction of the pharynx may thus occur. This is avoided to a large extent by elevation of the patient's chin and by holding the head back, the fingers of the anesthetist grasping the undersurface of the mandible for this purpose. If difficulty in the free passage of air is still present as shown by the forcible respiratory efforts of the patient, a curved, flattened, metal or rubber tube (called an airway) is inserted between the teeth above and behind the tongue to overcome the obstruction (Fig. 1).

For the relief of upper respiratory obstruction which will not yield to simpler methods or as an assurance that such obstruction will

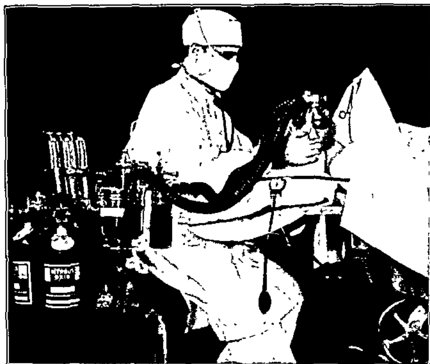


Fig. 1. Method of introducing anesthesia utilizing a "circle filter" type of apparatus. Jaw can be held forward by either the left hand holding the mask or the right hand pushing the ramus forward. A blood pressure cuff and stethoscope on the arm permit constant observation regarding the blood pressure level.

not ensue, an endotracheal tube may be used. A specially constructed catheter, large enough to almost fill the glottis, is passed through the larynx into the upper trachea. This method facilitates the use of positive pressure and is indispensable in operations on the widely opened pleural space and in operations about the head and neck where anesthetic apparatus would otherwise encroach on the surgical field.

Technics of Inhalation Anesthesia. The simplest method for the administration of volatile agents such as ether and chloroform is the *open drop* technic. The drug is dropped on a gauze-covered wire mask where it vaporizes and permeates the air being inhaled by the patient. Another simple but less commonly used method is *insufflation* in which air, laden with ether or some other agent, is blown into the mouth of the patient thus obviating the need for a mask. The most common method of administering anesthetic gases or volatile agents is that utilizing a gas machine by which the concentration of the agent in oxygen can be controlled. The amount and type of rebreathing are important features and are the basis for the following classification.

1. The *closed* method (carbon dioxide not removed) is one in which the anesthetic agent and oxygen are inhaled from a bag and closely fitting mask through which the gases are completely rebreathed. Owing to the rapid accumulation of carbon dioxide, this method is not physiologic and can be used safely only for very short periods.

2. The *semiclosed* method uses a bag and mask, but the flow of gases is maintained at a sufficient rate to eliminate much of the exhaled carbon dioxide and anesthetic agent through an escape valve. Some excess carbon dioxide usually develops. Moreover, the loss of anesthetic gases proves quite expensive.

3. In the *open* technic, the exhaled gases are prevented by a valve from being rebreathed, so that on each inhalation the patient receives a fresh mixture. Accumulation of carbon dioxide is avoided, but the expense is much greater because of loss of the anesthetic agent.

4. In the *carbon dioxide absorption* technic (Fig. 2), the anesthetic agent and oxygen

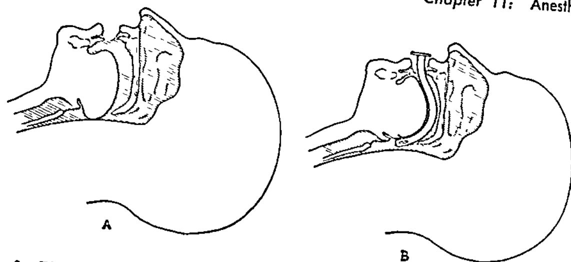


Fig. 2. Diagram illustrating the use of pharyngeal airway. A, obstruction caused by apposition of the tongue to the posterior wall of the pharynx; B, obstruction relieved by insertion of metal airway.

are rebreathed, but the exhaled carbon dioxide is removed by passage of the mixture through an absorbing chemical (e.g., soda lime). Oxygen is added constantly to replace that used by the patient, and the anesthetic agent is added as needed. This method is the most economic in conserving the anesthetic agent and has other distinct advantages. Two types of mechanical arrangement are used. With the "to-and-fro" system there is a canister of absorbent chemical inserted between the mask and bag, and the air is breathed back and forth through it. With the so-called circle filter (Fig. 3), the air passes around a one-way circuit through two breathing tubes leading to and from a canister of absorbent chemical on the machine, beyond which is a breathing bag. The direction of flow is controlled by valves.

Accumulation of carbon dioxide, or respiratory acidosis, is highly undesirable, and all efforts are made to avoid this. Convincing evidence of the harmful effects of excessive carbon dioxide has not yet been obtained in man, but certain facts seem established. Cardiac arrhythmias are more likely to develop during respiratory acidosis. This may be related to the liberation of norepinephrine and epinephrine by carbon dioxide. Sudden changes in carbon dioxide tension are reflected in changes in potassium balance. This may contribute to irregularities of the heart and to hypotension.

Respiratory Emergencies. The frequency of respiratory emergencies during and immediately following operation emphasizes the fact that the person giving the anesthetic should be well-trained and familiar with the various complications of anesthesia, since only prompt action of the correct type, often in cooperation with the surgeon (6) will avoid unnecessary fatalities.

1. Respiratory Paralysis. The cause of this complication may be central, as in the fourth stage of general anesthesia, or may be due to acute oxygen want; it may occur in spinal anesthesia, due to peripheral (phrenic and intercostal nerves) or central paralysis. In the absence of respiratory obstruction, efficient artificial respiration with air or oxygen will maintain life while the cause is detected and eliminated. Severe respiratory depression without actual paralysis, as may occur in very deep third stage anesthesia, although less dramatic, may cause serious results from oxygen want (hypoxia) if allowed to persist; the cerebral hypoxia may produce serious mental deterioration.

2. Acute Respiratory Obstruction. This may result from many causes common among which are the relaxed tongue falling back against the posterior wall of the pharynx; foreign bodies such as chewing gum, false teeth, sponges, vomitus, mucus, pus, and blood in the air passages; laryngospasm; tumors; edema. Acute respiratory obstruction precipitates respiratory efforts which are persistent and exaggerated until abolished by the ensuing acute oxygen want. These futile respiratory efforts have a characteristic appear-

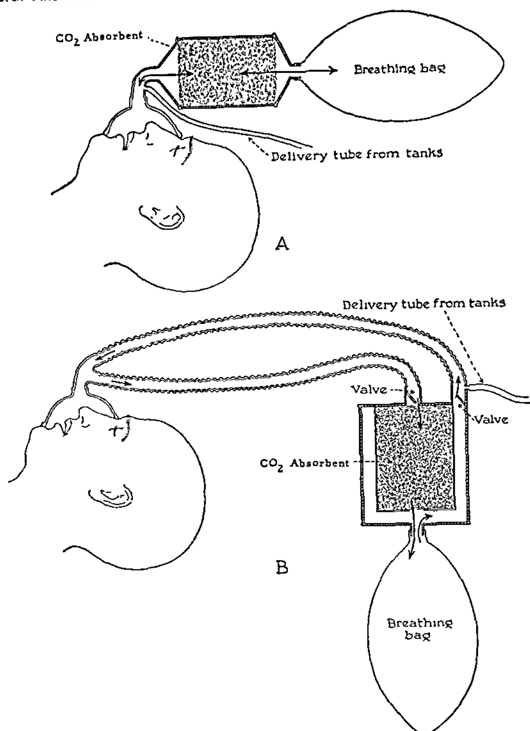


Fig. 3. Two types of carbon dioxide absorption technic. A, the "to-and-fro" type; B, the "circle filter" type.

ance—the abdomen expands while the chest is drawn in, particularly at the lower ribs, the sternum, and the suprasternal and supraclavicular regions. Treatment depends on the nature of the obstruction and may consist of elevating the chin, pulling the tongue forward, insertion of an airway or an endotracheal tube, digital or instrumental removal of a foreign body, and suction or gravity drainage of fluid from the pharynx or trachea. Any

obstruction at or above the larynx can be relieved by a quick tracheotomy if other methods fail. If acute oxygen want remains unrelieved and respiratory efforts have ceased, correction of the obstruction must be followed by artificial respiration (see page 179).

3. ACUTE OXYGEN WANT. Usually called *anoxia*, an acute lack of oxygen may result from interference with respiration or from the administration of a mixture containing too little oxygen. The outstanding signs are change in pulse rate to either tachycardia or a slow full bounding pulse; increased respiratory rate followed by respiratory arrest; muscular spasms resulting in movement of the limbs, vomiting, phonation, rigidity, or severe tonic convulsions. Cyanosis sometimes but not always occurs, since the appearance of cyanosis depends upon many factors including the amount of hemoglobin, the texture and color of the skin, and the distribution of the blood. The treatment is obviously to remove the cause and administer oxygen or air. It should be emphasized here that anoxia is to be meticulously avoided, regardless of the type of anesthesia used. Much harm is wrought by anoxia especially in poor risk patients and in those with circulatory shock (see Ch. 13).

In the treatment of acute respiratory emergencies, stimulant drugs or carbon dioxide are of little use particularly in the presence of obstruction. The essential thing is to supply adequate oxygen without delay and to remove the cause.

Cardiac Arrest. Cessation of cardiac activity due to acute cardiac failure, ventricular fibrillation, or autonomic reflex stimulation is fortunately much less common than cessation of respiration, but on the other hand it is much less likely to respond to treatment. Its possible causes should be avoided, particularly anoxia (7), hypercarbia, and unusual reflexes. If the heart stops, respirations will likewise soon cease, thus making artificial respiration necessary. Artificial respiration with oxygen, along with cardiac massage (better called manual artificial circulation), should restore cardiac rhythm and life if the cardiac arrest was detected as soon as it happened and proper measures were instituted immediately (within 4 minutes). By "manual artificial circulation" is meant firm but gentle intermittent compression of the heart about 60 times per minute to empty the heart; it refills of itself. This is best done by an approach through the chest. A lateral incision is made from the border of the sternum in the third or fourth left interspace, the adjacent cartilages are cut, and the ribs are spread apart. Time is important, but an effort must be made to maintain as aseptic a technic as possible. In the presence of efficient artificial respiration and artificial circulation, oxygenation of the tissues (particularly the brain) is maintained. If ventricular fibrillation develops, it will usually be necessary to use a defibrillator to restore rhythm, although the rapid injection of 20 ml. of 1 per cent procaine into one of the large arm veins may be tried first (8). Calcium chloride, 2 to 10 ml. of a 10 per cent solution, injected into the left ventricle may be helpful in initiating cardiac rhythm or in improving the beat if it is weak. In the defibrillated heart, epinephrine is dangerous.

A method of external electric stimulation which acts as an intracardiac pacemaker has been reported by Zoll and associates (9). Unfortunately this procedure is not always successful, and if it is not, it may prevent restoration of the heart beat by the conventional method of cardiac massage. Return of spontaneous cardiac action has occurred as long as 90 minutes after such treatment was instituted, ultimate recovery of the patient being complete. However, a complete cessation of cardiac action for more than six minutes is incompatible with life, even if cardiac action returns; this is due to the fact that there is functional death of the cells of the central nervous system, consequent to interruption of the blood supply.

ARTIFICIAL RESPIRATION

On numerous occasions, the anesthetist will be confronted with cessation of respirations produced by complications of anesthesia including overdose of anesthetic, anoxia, and overdose of preanesthetic drugs. When respiratory arrest occurs in the operating room, artificial respiration will be a comparatively simple matter since the ordinary gas machine is most effective for such a purpose. Obviously, when respiratory arrest is encountered

outside the operating room, other means must be adopted.

Waters (10) has emphasized four facts about artificial respiration: 1. gentle intermittent inflation of the lungs with air can serve as an adequate substitute for normal breathing; 2. if oxygen is available, it may be used; 3. regardless of the method employed, air cannot enter or leave the lungs if the air passages are obstructed; and 4. elaborate equipment is not essential.

A simple *mechanical method*, described in detail by Waters (10), which eliminates the need for elaborate machines, consists of the use of an oxygen tank, a rubber bag, and a face mask. The valve of the oxygen tank is opened, and the mask is applied to the face. Interchange of oxygen is achieved by alternately squeezing the bag and releasing it. With this method, it is essential to be sure (as in other methods) that a free interchange of gas to and from the lungs is obtained. Firm pressure against the angle of the jaw forcing it forward will usually correct obstruction caused by the tongue falling backward, which is probably the most frequent and important cause of obstruction to artificial respiration.

Without question one of the most useful and most neglected methods of artificial respiration is *blowing into the patient's nose or mouth* (Fig. 12, p. 180). This is often called the mouth-to-mouth method (11). It may be necessary to lift the jaw forward to allow free passage of the air into and out of the lungs. In addition to the use of the gas machine mentioned above, several manual methods are available. The *Nielsen Method*, consisting of alternately lifting the arms and pressing on the back with the patient in the prone position, is effective (Fig. 13, p. 181). The *Schaefer Method* consists of pressure over the lower part of the dorsum of the chest by the operator's hands with the patient in the prone position. The *Silvester Method* is performed with the patient in the supine position; it consists of expansion and deflation of the patient's chest by elevating the patient's arms to full extension over his head (equivalent to inspiration) and deflation of the chest by pressure of the arms against the chest. In the *Eve method* the patient is placed on a door or large board balanced in the middle, and the patient's head is alternately elevated and lowered; the weight of the liver causes upward and downward movement of the diaphragm with resultant exchange of air in the lungs.

After a study of eight of the more commonly used methods (excluding use of mechanical devices), Gordon and associates (11a) found that a back-pressure hip-lift method combining the Schaefer (prone pressure) and Emerson (hip lifting) methods resulted in the interchange of almost twice as much air as with any other method.

AGENTS USED IN GENERAL ANESTHESIA

Although ether was one of the first anesthetic agents discovered, it is still used and perhaps more commonly than any other. However, numerous other agents have been introduced in the past two or three decades, many of which have specific advantages for certain types of patients or operations.

Ether. Diethyl oxide ($C_2H_5OC_2H_5$) was first used as a surgical anesthetic in Jefferson, Georgia, by Dr. Crawford W. Long, who in 1842 painlessly removed a tumor from the neck of a patient. Its widespread use followed an independent public demonstration of its value at the Massachusetts General Hospital in Boston in 1846. Ether (also called sulphuric ether) is a volatile liquid which is administered by inhalation of the vapor, which, in a warm atmosphere, is rapidly given off by the liquid.

ADVANTAGES OF ETHER. It is probably the most widely used general anesthetic for the performance of operations requiring good muscular relaxation. It is also used extensively in children. It has a wide margin of safety; i.e., there is a considerable range between the amount of ether which produces anesthesia and the amount which is toxic. Ether is one of the most convenient of inhalation anesthetics since it requires only a simple gauze mask for its administration and is perhaps the safest in inexperienced hands.

DISADVANTAGES OF ETHER. The slight though definitely deleterious action of the drug itself on liver cells makes it somewhat dangerous in patients suffering from a severe degree of hepatic disease. In surgical shock it is especially hazardous since it has an un-

favorable effect on a falling or low blood pressure. It does not act as rapidly as other anesthetics and is not, therefore, advisable for short operations. Ether tends to increase the postoperative nausea and vomiting. Its flammable property makes it dangerous when a hot cautery or flame is being used in the operating room, although some of the gases are probably more hazardous in this regard.

Nitrous Oxide. Though known before as an interesting gas, nitrous oxide was first used as an anesthetic agent in 1844 by Dr. Horace Wells, a dentist of Hartford, Connecticut, for the extraction of teeth. Nitrous oxide (N_2O) was originally called laughing gas because of the hilarious mood it sometimes provoked in patients. It is always given mixed with oxygen in varying percentages and is, of course, administered with a gas machine. Nitrous oxide will support combustion as does oxygen but is not, itself, combustible or explosive. It is not a very potent anesthetic.

ADVANTAGES AND DISADVANTAGES. Nitrous oxide acts fairly rapidly; its effect is over just as quickly, and there is no disagreeable odor as is true of ether. It produces very little muscular relaxation, since at best it can produce only first plane anesthesia (of the third stage) and in some individuals not more than second stage anesthesia without severe oxygen want. Its margin of safety is not very wide even though the gas is in itself not toxic, because its effectiveness depends on a rather high concentration of the gas, often as high as 90 per cent or more, thus leaving less than 10 per cent of oxygen to carry respiratory function. Asphyxia, therefore, is the dangerous feature in nitrous oxide anesthesia and requires expertness to avoid it. It is thus a more difficult anesthetic to give than ether. The rise of blood pressure and slowing of the pulse rate by nitrous oxide are apparently due to the effect of asphyxia.

Nitrous oxide–oxygen inhalation finds an ideal application in short operations when relaxation is not essential. It is used most commonly in the extraction of teeth, incision and drainage of abscesses, skin grafting, and removal of superficial tumors. It may be given after any of the basal anesthetics mentioned and, with their aid, may bring about sufficient relaxation to permit pelvic and abdominal operations.

Nitrous oxide is a weak anesthetic; however, this disadvantage can be overcome by increased dosage of preanesthetic drugs. Moreover, these drugs, including also thiopental sodium and barbiturates, may be given intravenously during the anesthetic. To obtain relaxation, one of the muscle relaxants may be given. Addition of these drugs will allow a greater concentration of oxygen and thus minimize the danger of anoxia which is so apt to develop in nitrous oxide anesthesia.

Diffusion anoxia may develop after nitrous oxide anesthesia because the pulmonary alveoli and blood contain nitrous oxide, and, with the first inhalation of room air, nitrogen begins to diffuse into the blood and nitrous oxide into the alveoli. Since nitrous oxide is more soluble in blood, the amount of this gas available for diffusion outward into the lung is greater than the amount of nitrogen replacing it in the blood. This results in a net gain in the gas volume of the lung, and the lung merely expels gases instead of expanding. To prevent this diffusion anoxia, a high concentration of oxygen should be maintained at the end of administration of the anesthetic as the nitrous oxide is being eliminated.

Ethylene. This gas (C_2H_4) is only slightly more potent than nitrous oxide, but it has a slightly pungent, disagreeable odor and it is explosive. It is not used extensively.

Cyclopropane. This gas is a much more powerful anesthetic agent than nitrous oxide or ethylene; it produces greater relaxation and is effective with a much higher concentration of oxygen. It is thus particularly useful when respiratory disease is present. Since it is explosive, it cannot be used in the presence of a cautery. It slows the heart rate through a mechanism which is poorly understood. It will occasionally produce cardiac arrhythmia. It is particularly valuable as a substitute for ether when the operation requires muscular relaxation; however, relaxation is not as complete as with ether. The muscle relaxants (see page 209) remedy this deficiency by producing sufficient relaxation to perform any celiotomy. It is a very good anesthetic for patients in hemorrhagic shock because of its tendency to increase blood pressure.

Divinyl Ether. This volatile liquid is flammable and deteriorates on exposure to air. It has a narrow margin of safety. Divinyl ether

has a rapid action with a short induction period and quick recovery. Its use has been limited largely to operations requiring but a short period of anesthesia because, with prolonged use, there is danger of renal and hepatic damage. It may be used as an induction agent to be followed by open drop ether.

Chloroform. Chloroform ($CHCL_3$) was first used in Scotland by Sir James Y. Simpson in 1847 and thus was really introduced contemporaneously with ether. Chloroform is a volatile liquid and is administered by inhalation of its vapor as is ether. It produces rapid anesthesia, excellent relaxation, and is not flammable; however, its toxic effects on the liver, its narrow margin of safety, and the considerable danger of causing cardiac arrest have made it unpopular in this country.

Allied to chloroform is *ethyl chloride,* a still more volatile liquid which evaporates so rapidly that it is used (frequently unsuccessfully) as a local anesthetic by freezing the sensitive skin over an abscess. Sprayed over or dropped upon a gauze mask as an inhalation anesthetic, it produces a rapid anesthesia, but, with such a narrow margin of safety, it cannot safely be used for operations which last more than a few minutes.

Barbiturates. Thiopental (pentothal sodium) and thiamylal (surital sodium) are short-acting derivatives of barbituric acid and induce anesthesia by intravenous administration. Pentothal sodium produces an immediate, though short-lasting, anesthesia, i.e., 10 to 20 minutes. The duration of anesthesia may be extended by giving intermittent injections as required. The total dose varies greatly (1 to 3 gm.) depending upon the duration of the anesthesia, the type of patient, and the degree of preoperative narcosis. Great care must be exercised to place the needle in a vein and not an artery because injection into an artery has been known to produce gangrene of an extremity. Respiratory depression must be avoided by watching the patient's respiration. These drugs have the advantage of being safe in the presence of cautery. They are used for short operations, for operations which do not require deep anesthesia, for operations on patients in whom a gas–oxygen or other inhalation anesthetic is inconvenient or inadvisable, and for such procedures as incision of abscesses, reduction of fractures, and amputations. They are also widely used as a method of "induction" preliminary to other methods, including intratracheal anesthesia. Some anesthetists combine them with muscle relaxants for laparotomies. In the hands of competent anesthetists, they have proven useful and comparatively safe. Since these drugs are detoxified by the liver (12), action is prolonged; their margin of safety is probably less in patients with hepatic disease. Also, these drugs can produce a serious drop in blood pressure.

Avertin. This drug is usually considered a basal anesthetic agent and, formerly, was given as an enema in the patient's room. It is no longer employed because of its toxicity and depressant action on blood pressure. It produces a complete unconsciousness which, with large doses, lasts several hours. Though total anesthesia is not desirable, the amount of ether or gas necessary after its use becomes considerably diminished.

Muscle Relaxants. In abdominal operation, muscle relaxation is necessary to allow easy access to various organs and operations upon them. The first of these agents to be used (1940 to 1941) was d-tubocurarine (curare). Numerous others including succinylcholine, dimethyl-d-tubocurarine iodide (Metubine), decamethonium bromide (Syncurine), and gallamine triethiodide (Flaxedil) are available. These drugs are not anesthetic agents but produce their effects by relaxation and paralysis of skeletal muscle, presumably by preventing acetylcholine from reaching the receptor area of the muscle cell membrane. The drugs used most commonly are d-tubocurarine and succinylcholine; their clinical dosages are approximately 18 and 30 mg., respectively; the time required for action is 90 to 150 seconds for the former and 30 to 75 seconds for the latter. One of the disadvantages of succinylcholine is its tendency occasionally to produce apnea.

The effects of these drugs last from 40 to 50 minutes; after lapse of this time, the drugs may be repeated in smaller doses. They can be used with any anesthetic, but, if used with ether, the dosage must be greatly reduced, because the effects of these two drugs are synergistic. Overdosage results in respiratory paralysis which must be treated with artificial

respiration. Prostigmine is a physiologic antidote.

REGIONAL ANESTHESIA

A common misconception about local anesthesia is that it involves no danger. Actually the hazards are far from negligible; although they are uncommon, one should be thoroughly familiar with the various toxic reactions before using local anesthesia. The *toxic effects of local anesthetic drugs* are too often regarded as mere nervousness. Actually they consist of both circulatory and neurologic manifestations; e.g., there may be nervousness, talkativeness, excitability, delirium, convulsions, weakness, faintness, palpitation, nausea, vomiting, pallor, falling blood pressure, slow or fast pulse, loss of consciousness, complete circulatory collapse, and death. Many of these effects are due to sensitivity (allergy). The possibility of a toxic reaction may be predicted by noting any history of idiosyncrasy and minimized by use of the smallest volume and lowest concentration required, by use of epinephrine to reduce the rate of absorption when used for infiltration, by slow injection, and by avoidance of intravascular injection. Neurologic reactions may be minimized by preliminary administration of a barbiturate, but this has no prophylactic effect on circulatory reactions. Should a toxic reaction occur, the maintenance of respiration is mandatory—by artificial respiration if necessary. Administration of a barbiturate intravenously may be employed to control convulsions. Epinephrine may be given cautiously for circulatory collapse (low blood pressure, bradycardia, or, less commonly, tachycardia) if a reaction to it can be ruled out. Since the potency and toxicity of the various drugs differ considerably, it is not safe to substitute one for another without being thoroughly acquainted with the peculiarities of each. It is also important to always use similar technic, particularly in spinal anesthesia, because injudicious variations from the procedure with which one is familiar may result in numerous complications, some of which may be disastrous.

Cocaine. This agent is useful in solution (5 to 10 per cent) to anesthetize mucous membranes, notably in the oral and pharyngeal cavities. It need not be injected for this purpose but merely applied to the area with a pledget of cotton. It is also used to anesthetize the conjunctiva, urethra, and bladder. In preventing the gag reflex during the passage of a stomach, duodenal, or nasal tube, it finds a useful place. It has the disadvantage of being toxic and habit forming and, for hypodermic use, has been superseded by a related drug, procaine hydrochloride.

Procaine Hydrochloride (Novocain). Procaine is perhaps the most widely used of the local anesthetics. It is an ester of para-aminobenzoic acid and diethylaminoethanol and was synthesized by Einhorn in 1905. The advantages of procaine are low cost, low toxicity, and ease of sterilization without danger of change or loss of action. The disadvantages are its short action and lack of topical activity. It is used in concentrations varying from 0.25 to 2 per cent.

Lidocaine (Xylocaine). This is particularly useful because of its rapid onset of action, its greater spreading ability, and its longer duration of action.

Other Agents. Numerous *other agents* are available for local anesthesia. *Dibucaine hydrochloride* (*Nupercaine hydrochloride*) is also useful when prolonged anesthesia is desired. Its greater toxicity is neutralized by the low concentration needed for anesthesia. *Pontocaine hydrochloride* is similar to procaine but is more effective on mucous membranes; it is also used in spinal anesthesia. *Metycaine hydrochloride* is used for spinal anesthesia, its action being slightly longer than that of procaine.

METHODS OF ADMINISTRATION OF LOCAL ANESTHETICS. These agents may be given in numerous ways.

1. Local *infiltration* (Fig. 4) is perhaps the method most commonly used; it is begun by forming a wheal in the skin using a hypodermic needle which is introduced into the derma. A 0.5 to 1 per cent solution is usually used. Anesthesia is due in part to the pressure on the nerve endings destroying their sensitivity and thus may be achieved with plain water which, however, loses its effect as soon as the wheal disappears (5 to 10 minutes). Procaine hydrochloride has, in addition, an anesthetic effect on the nerves themselves, and hence its effect lasts longer (30 minutes).

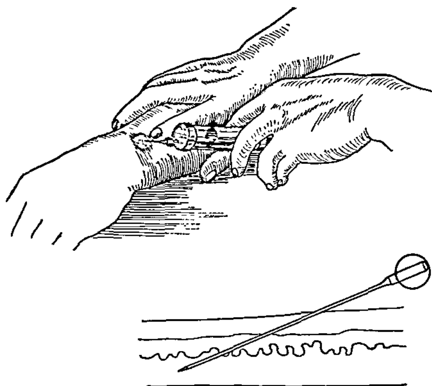


Fig. 4. The local infiltration of Novocain. Note the formation of a wheal in the skin. This is produced by injecting the agent into the derma as shown in the lower insert. This wheal establishes a painless portal of entry for the further injection of Novocain.

Epinephrine (5 drops of a 1:1,000 solution to each 100 ml.) causes vasoconstriction and thus prolongs anesthesia by diminishing absorption. Once this anesthetic portal of entry is made, the rest of the process is painless and simply consists of completing the infiltration of the skin and operative field.

Procaine may also be injected into the hematoma at the site of a fracture (10 to 30 ml. of a 1 per cent solution) and often achieves sufficient anesthesia to enable satisfactory reduction, especially of the small bones such as the radius and ulna.

2. *Block anesthesia* or *nerve-blocking* can be used to produce anesthesia in almost any part of the body. A solution of 1 to 2 per cent procaine hydrochloride is usually used in adults; a few milliliters are injected in direct proximity to the nerve supplying the area to be anesthetized. Brachial plexus block is particularly useful in certain patients with fractures and other injuries of the upper extremity. This important application of local anesthesia was discovered by Halsted, according to an award made to him by the American Dental Society in 1922. Bilateral block of the intercostal nerves will give fair relaxation for laparotomies. Splanchnic anesthesia, obtained by infiltration of the prevertebral tissues of the upper abdomen (by the anterior or posterior route) so that the splanchnic fibers and celiac plexus are blocked, is still used in parts of the world with limited facilities but is seldom employed here because other more satisfactory agents are available.

3. *Spinal anesthesia,* properly given in selected patients, has achieved a widespread use in recent years and competes successfully with the various forms of general anesthesia in certain clinics and in certain operations. The great advantage of a successful spinal anesthesia is the flaccid paralysis it produces which, in robust, muscular, and obese individuals, means an even more complete relaxation of the abdominal muscles than follows ether narcosis. For difficult intraperitoneal operations this is particularly valuable. Spinal anesthesia, moreover, does not produce a loss of consciousness, a feature which many patients and anesthetists prefer. Spinal anes-

thesia is also useful diagnostically in peripheral circulatory disease.

One of its disadvantages is its relative lack of control; once the full dose is given, its effects follows, and there is no method of stopping it as one may do with inhalation anesthetics. This defect can be overcome by "continuous" spinal anesthesia which is achieved by introducing a catheter into the subarachnoid space and introducing procaine in small doses as needed. Spinal anesthesia paralyzes the autonomic as well as the spinal nerve fibers, and, while the resultant fall of blood pressure may be minimized, its deleterious action on the circulation makes it dangerous in patients susceptible to circulatory impairment such as low blood pressure, heart disease, and late low intestinal obstruction. The danger of producing injury to the spinal cord itself is remote. Permanent neurologic signs and symptoms have been observed following spinal anesthesia, but they are usually related to errors in technic. Listed in order of increasing duration of effect, the drugs commonly used are procaine hydrochloride, pontocaine hydrochloride, and nupercaine hydrochloride. With the exception of nupercaine hydrochloride, the effect of the drug nearly always wears off in from one to two hours. The effect of nupercaine hydrochloride lasts much longer.

Many methods of administration have been reported, but the one commonly used consists of removing 2 to 5 ml. of spinal fluid by lumbar puncture, dissolving in it 50 to 200 mg. of specially pure procaine hydrochloride crystals, and reinjecting the fluid after solution is complete. The amount of fluid injected, the dose of the drug, the rapidity and force with which the fluid is reinjected, the specific gravity of the fluid, and the slope of the patient's spine determine the level and, in part, the duration of the anesthesia. The dose of pontocaine hydrochloride is about 8 to 20 mg. Nupercaine hydrochloride is usually used in a 1:1,500 solution of which 8 to 20 mg. are given.

In a follow-up study made by Vandam and Dripps (13) of 8,460 individuals given 10,098 spinal anesthetics, 0.8 per cent had residual signs or symptoms of numbness following their anesthesia. In the vast majority of patients, the numbness was restricted to the lumbar and sacral areas of the body. Most of the complaints had disappeared after six months. There were no other neurologic sequelae such as transverse myelitis, meningitis, or arachnoiditis.

4. *Epidural anesthesia* is obtained by blocking the spinal nerves in the epidural space just after they emerge from the dura and before they pass into the intervertebral foramina. The injection may be made at various levels—thoracic, lumbar, and caudal. The needle is introduced slowly between the spines of the thoracic or lumbar vertebrae through the interspinous ligament, and still more slowly through the ligamentum flavum, stopping short of the dura limiting the subarachnoid space. The chief advantage of a thoracic or lumbar epidural anesthesia is the fact that a segmented analgesia can be obtained. The chief disadvantage of epidural anesthesia is its uncertainty and technical difficulty; occasionally anesthesia is not obtained.

Caudal (sacral) anesthesia is a type of epidural anesthesia. It is useful in operations about the external genitalia and anus. It is administered by inserting a needle into the sacrococcygeal notch through the skin and ligament into the epidural space (Fig. 5). About 30 to 40 ml. of a 1 per cent procaine hydrochloride solution can be injected at this site. This bathes the emerging sacral nerves and, in most instances, produces a satisfactory anesthesia of the saddle type. The great disadvantage is its uncertainty; in 10 to 20 per cent of cases, anesthesia is not produced. The anesthesia is more certain if several of the sacral foramina, particularly the second, are also injected with about 5 ml. of 1 per cent procaine hydrochloride. Such procedures as hemorrhoidectomy and cystoscopy can be performed with this type of anesthesia. In recent years xylocaine, pontocaine hydrochloride, and cyclaine have become perhaps the three most popular anesthetics used for caudal anesthesia (14).

5. *Therapeutic nerve block* should be included under local or regional anesthesia and has many applications as discussed in other parts of the text. Indeed, use of alcohol instead of procaine often leads to permanent interruption of pains and spasm; the disad-

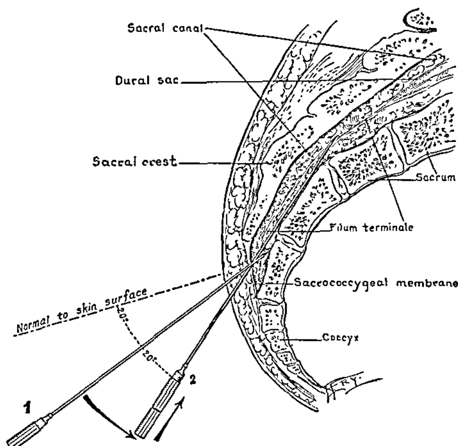


Fig. 5. Caudal block. Longitudinal cross section of the lower vertebral column is shown, including the manner by which a local anesthetic is introduced into the extradural space. After piercing the sacrococcygeal membrane, the needle impinges on the anterior wall of the sacral canal and passes from position 1 to position 2 in direction of the arrow. (From Labat. Regional Anesthesia, W. B. Sunders.)

vantage is that occasionally a painful neuritis rather than anesthesia follows.

Freezing. A momentary anesthesia can be brought about by freezing the part to be incised with an ethyl chloride spray; however, this is followed by mild pain after the frozen tissue thaws out. Another disadvantage is that freezing hardens the tissue and makes incision a little more difficult; this, however, may be obviated by using a sharp bistoury knife. Freezing has the great advantage of simplicity and speed but finds almost its sole use in very superficial abscesses when the skin is still too sensitive to be incised without anesthesia. When the abscess is deeper and the overlying skin uninvolved, it is far better to infiltrate with procaine or to resort to general anesthesia.

Refrigeration in Anesthesia. This procedure (originally utilized by Allen) is applicable chiefly to the lower extremity. In reality it is not a type of anesthesia but should be classified as a method of preoperative preparation. Ice bags are placed around the leg proximal to the site of operation. After one-half hour, the area is numbed sufficiently to tolerate the application of a tourniquet (two layers of half-inch rubber tubing). The limb is then packed in chipped ice from above the tourniquet to the toes. After several hours (two to four), when the temperature of the limb has dropped to within a few degrees of the freezing point, there is complete analgesia; amputation or other operations on the extremity can then be performed. The ice is, of course, removed, but the tourniquet is left on until near the end of the operation. This method of anesthesia is laborious, and its application is limited. It may be of advantage in cases of gangrene or severe injury when shock is pres-

ent. However, Large and Heinbecker (15) have shown that refrigeration results in retardation of healing of tissue so treated.

CONTROLLED HYPOTENSION IN ANESTHESIA

In an effort to reduce loss of blood during operation, hypotension is occasionally induced deliberately, particularly in operations where excessive hemorrhage is expected or in procedures where bleeding interferes with the operation, e.g., brain tumors. It is hoped that the operation will be shortened by decreasing blood loss. Originally, hypotension was induced by spinal anesthesia. More recently sympatholytic drugs, e.g., thiophanium d-camphorsulfonate (Arfonad) and hexamethonium, have been used for this purpose. Under such circumstances, the hypotension is essentially neurogenic without peripheral constriction and perhaps under better control than when spinal anesthesia is used. There is no evidence that the oxygen supply to the tissues is hampered, but coronary blood flow is probably decreased; however, the hazard of reduced coronary flow is lessened to a great extent by the diminished workload required of the heart during hypotension.

The drugs are given intravenously by drip until the systolic pressure reaches the desired level, usually between 70 and 80 mm. Hg. Discontinuance of the drug results in a rapid return of pressure to normal within a few minutes. While the pressure is being maintained at levels mentioned above, the patient must be kept in a horizontal position, since elevation of the head might result in dangerous cerebral ischemia. If vasopressin drugs are indicated because of failure of the pressure to return to normal, the dose must be kept extremely small, because the usual dose may cause a dangerous rise in blood pressure (16).

HYPOTHERMIA AS ANESTHESIA

To a great extent, the needs of intracardiac surgery have been responsible for the development of hypothermia in anesthesia. With hypothermia, the surgeon can interrupt the blood-pumping function of the heart for longer than three or four minutes, which is the safe limit in a patient with a normal body temperature. As hypothermia reduces body metabolism, even the brain can survive cessation of circulation for 20 minutes or more, thus allowing the surgeon time to repair defects in the open heart.

McQuiston (17) was one of the first to demonstrate that mild hypothermia (1 to 3° C.) exerted a protective effect in the operative management of cyanotic heart disease. During the next few years, the pioneer work of Bigelow (18), Swan (19), and others demonstrated that hypothermia of several degrees (down to 28° C.) is helpful in cardiac surgery.

Body temperature can be lowered by a variety of methods, such as immersion in ice water, wrapping in "cold" blankets, and direct cooling of blood. With a reduction of body temperature, the heart rate slows, the blood pressure falls, respiration becomes slower, and cardiac output diminishes. Anesthesia is needed for the induction of hypothermia; however, once the temperature drops below 28° C., anesthesia is sufficient to allow operative procedures without any other agent. However, at this temperature ventricular fibrillation becomes a hazard and is increasingly common.

TOXICITY AND DANGERS OF ANESTHESIA

Anesthesia implies a deliberate, artificial, physiologic disturbance. Loss of consciousness, loss of response to painful stimuli, and loss of muscular tone are obvious examples of the disturbances of physiology which are deliberately produced to facilitate surgical procedures. Unfortunately many undesirable effects are likely to be produced at the same time.

Respiratory disturbances include depression, obstruction, reduction of protective cough reflex, and increased secretion. The gastrointestinal system may be affected with resultant nausea, vomiting (with the possibility of aspiration of vomitus), increased salivation, and altered intestinal motility. If vomiting persists in the postoperative period, it interferes with normal nutrition, results in loss of fluids and chlorides, and may seriously affect the patient's convalescence.

Serious *circulatory disturbances* may result

from anesthesia. There may be circulatory depression contributing to shock, changes in pulse rate, changes in the distribution of blood, and sudden cardiac arrest.

Beside the obvious effects on the *nervous system* (loss of consciousness, loss of reflexes) there may be other serious disturbances. Excitement may result in injury to the patient or others. Convulsions may occur. These are usually associated with increased body temperature (hot weather, heavy drapes) and carbon dioxide excess. The autonomic nervous system is also affected. Some agents stimulate the sympathetics while others stimulate the parasympathetics. The size of the spleen, an important consideration in splenectomy, may be altered. Ether contracts the spleen and is, therefore, the agent of choice for splenectomy.

The *acid-base balance* is disturbed usually toward the acid side. Not only do some agents cause an acidosis, but also respiratory depression and the probability of some rebreathing of the expired atmosphere result in accumulation of carbon dioxide and further acidosis.

Liver function is depressed by most anesthetic agents, particularly chloroform, and by oxygen want. Recovery is usually rapid, but in cases with preoperative liver damage the additional impairment may be serious. The damage may be minimized by preoperative dietary preparation designed to increase the carbohydrate and protein and reduce the fat content of the liver. Also, the use of a high oxygen atmosphere during anesthesia is helpful. Based upon a study of liver function tests, Boyce (20) noted that there was a depression of liver function following practically all anesthetics. Of the various agents tested by him, this depression was noted following chloroform, spinal anesthesia, ether, and ethylene with a degree equivalent to the order named. He explained the serious depression following spinal anesthesia on the basis of the fall in blood pressure resulting in a decreased oxygen supply to the liver. Although cyclopropane was not tested, Boyce was of the opinion that it would be followed by a minimal amount of hepatic depression because of the high oxygen content of the gaseous mixture used. Maddock and associates (21) approximated the degree of hepatic injury following anesthesia by determining the glycogen content of the liver. In these experiments, the average glycogen content for the normal liver was 3.96 per cent, whereas it was 3.15 per cent following spinal anesthesia. The glycogen content in patients with normal livers was raised to an average of 5.03 per cent by supplementary glucose feedings for 12 hours preceding operation. However, the operation itself will naturally be a factor in depressing liver function.

Kidney function is also depressed by anesthetics. A decrease in glomerular filtration (persisting for a few hours to a week) has been noted following anesthesia induced by ether, cyclopropane, and avertin. The decreased function may be related to the amount of blood lost and the severity of the blood pressure fall. Serious acidosis may result from renal impairment.

Another physiologic disturbance produced by anesthesia which is too often overlooked is the *impairment of heat regulation*. In hot weather the patient may develop hyperpyrexia which may contribute to shock, disturbed metabolism, increased oxygen demand, and in some cases to the development of convulsions. This is particularly true of operations upon patients with hyperthyroidism. In general, such operations should be performed in hot weather only when an air-conditioned room is available for the operation and during the postoperative course. In hot weather the amount of sterile drapes should be held to a minimum; in fact, if the patient appears warm, his legs should be uncovered and cold wet packs applied.

Many of these disturbances may result from local or spinal anesthetics. Convulsions, circulatory collapse, and oxygen want may be cited as examples.

Only the well-trained physician anesthetist collaborating with the rest of the surgical team can appreciate all these disturbances of physiology and, by the judicious choice of anesthetic agents and technics, minimize their seriousness.

Explosion hazards are numerous in anesthesia. Of the common inhalation anesthetics, only nitrous oxide and chloroform are non-explosive. Obviously, rectal avertin, intravenous and regional anesthetics are not explosive. The source of ignition may be artificial, e.g., cautery, flame, or spark from electric

apparatus, or it may be a spark due to static electricity. Electric apparatus should be designed to avoid unexpected sparks, and, when a known source of ignition (e.g., cautery) is to be used, the anesthetist should avoid explosive agents. Static sparks are more difficult to anticipate and are an ever present hazard. High relative humidity, proper (moderately conductive) flooring, and avoidance of wool blankets can reduce the danger. Nevertheless, any moving person may accumulate a static charge which, if discharged near an explosive anesthetic, may result in a fatality. Nylon uniforms tend to create static electricity and should be prohibited. Most important is the fact that rubber- or composition-soled shoes insulate the wearer and promote the accumulation of static electricity. *Only leather-soled shoes (or those with specially designed conductive soles) should be worn in the operating room.* Rubber heels are not prohibited.

The *death rate* from anesthesia has recently been studied by Beecher and Todd (22). In a report containing data from 559,548 surgical patients in 10 different institutions between 1948 and 1952, they noted an over-all rate of 1 in 1,560 patients. Deaths were disproportionately higher in the first decade of life and in the latter decades. Since more than one agent was given so often to the patient, it was difficult to obtain an accurate rate for each of the drugs used during this period. However, the assignment of deaths to the various agents, to the best of the ability of the workers contributing to this study, revealed the highest death rate for curare, being 1 in 370 patients or six times as high as the control series of 1 in 2,100. The lowest rates were with regional and spinal anesthesia, being 1 in 2,330 and 1 in 1,780 respectively. The rate for ether was 1 in 820, approximately the same as for cyclopropane.

COMPLICATIONS DURING ANESTHESIA

Under this heading will be discussed some of the more important complications related primarily to the operation. Since the manifestations of these complications are usually detected readily by the anesthesiologist, it is essential that he be watchful of their development so that prophylactic and therapeutic measures may be instituted early. In fact, the anesthesiologist should keep the surgeon informed of any evidence of deterioration of the patient's physical condition so that the surgeon may modify or terminate the operation as indicated.

Aged and poor risk patients are slightly more prone to develop complications from anesthesia than are other patients. Age itself is no contraindication to anesthesia, but complicating diseases may indicate certain anesthetics to be preferable to others, as discussed in detail by Adriani (23).

Shock is one of the most common complications occurring during major operations and is detected by fall in blood pressure, tachycardia, pallor, and sweating. *Transfusion reactions* occurring during operations are obviously very serious and should be detected as early as possible; important manifestations are cyanosis, unexplained cardiac irregularity, excess oozing of blood from the operative site, hemolyzed serum or plasma, and hemoglobin in the urine. Development of *atelectasis* during operation is not uncommon; it may be detected by tachycardia, hyperpnea, cyanosis, lack of movement on the affected side, and other manifestations commonly observed. Fortunately, it can usually be corrected promptly by aspiration of the obstructing debris from the bronchus leading to the affected lobe or lung.

Cardiac irregularities are particularly common during operations on the heart or lungs. Intravenous procaine hydrochloride is quite effective in prophylaxis and treatment, but its use is so often followed by serious hypotension (24) that therapy should probably be limited to treatment and not prophylaxis. Procaine amide has been reported effective by Rovenstine and associates (25) in the ventricular tachycardia and extrasystoles occurring in patients undergoing thoracic operations, particularly under cyclopropane anesthesia. They found the drug useful in prophylaxis as well as in therapy.

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12

SYSTEMIC REACTION TO TRAUMA

John M. Howard

Every serious wound produces certain nonspecific systemic effects on the body as a whole, as well as disturbances in organs or systems far removed from the wound. These remote results of injury often prove of greater consequence in the recovery of the patient than the wound itself. Certain systemic effects of a severe wound are obvious, such as pain and fever, anemia from loss of blood, prostration, immobility, and anorexia. In themselves, these are responsible for many changes in the body as a whole. Such other consequences as shock, metabolic changes, the so-called pituitary-adrenal reaction, changes in cell permeability, and hepatic, renal, and gastrointestinal impairment are also important. It will be the purpose of this chapter to discuss these systemic and outlying effects of injury with special reference to possible therapy designed to combat their potential harmful results while at the same time to evaluate and recognize their beneficial influences.

HISTORICAL SURVEY

It must have been obvious to the earliest observers that the seriously wounded frequently became ill and many died, either early or late, for reasons not directly connected with the wound. The earliest biochemical evidence of a serious metabolic disturbance after a severe wound was noted by Malcolm (1) who, in 1893, found a large increase in the urea output in the urine. This evidence of an increased destruction of tissue protein was observed in 1909 by Shaffer and Coleman (2), in studies on typhoid fever.

It was Cuthbertson (3) however, who, in 1929, first studied in detail what he called the "catabolic response to injury" and even attempted to explain its significance. He believed that it was a mechanism on the part of nature to provide certain nutritional elements necessary for life from the breakdown of protein tissues during periods when the animal was unable to obtain exogenous nourishment. This process, later given the more elegant name of gluconeogenesis, rapidly breaks down normal tissue protein to yield amino acids, of which many may be utilized as such and others are deaminized to provide energy. The increased output of nitrogen in the urine, however, not only originates from the catabolism of normal protein tissue but, in accidental and operative trauma, there is a breakdown of damaged protein tissue and of extravasated plasma protein and hemoglobin. Other changes, especially in salt metabolism, were later observed. Mention should also be made of the work of Walter Cannon (4) who carefully studied the systemic effects of rage, fear, pain, and other emotions which are, of course, known to accompany injury of various kinds including tissue trauma.

The discovery that the adrenal cortex plays an important role in the systemic response of the body to injury is more recent. Quite early, repeated observations showed that animals deprived of their adrenal glands either died or, when kept alive by such means as high salt intake, were unable to withstand the effects of even slight trauma or moderate changes in environmental temperature. In

such animals, stress of any kind produced profound systemic disturbances. Slight hemorrhage was followed by severe shock. Addison's disease in humans produced a similar clinical state and was also due to destruction of the adrenal cortex. Only by administering whole adrenocortical extract in sufficient doses to adrenalectomized animals could they withstand even mild stimuli which might be considered normal since they are being continually overcome. To a similar but lesser extent, hypophysectomy had the same effect. That the adrenals were normally stimulated by harmful influences seemed a logical inference. Selye (5), who has done much to advance this idea, called this adrenocortical response a "stress" or "alarm reaction," believing that it represented a defensive mechanism to be compared with a "call to arms." He found, among other things, that persistent stress in animals led to enlargement of the adrenal gland. The role of the pituitary gland was suggested when it was found that the adrenal changes failed to occur after hypophysectomy. Later, the isolation and use of ACTH (adrenocorticotropic hormone) confirmed the importance of the pituitary in the stress reaction, for it, like stress, produced evidence of adrenocortical stimulation in animals and in humans. This brings us back to the work of Walter Cannon (4), who showed that the effect provoked by rage, fear, and pain, was due to the release of epinephrine from the medulla of the adrenal. It was later shown that epinephrine itself directly or indirectly stimulates the pituitary and thereby adrenocortical activity. For example, Long and his co-workers (6) have demonstrated that the subcutaneous injection of epinephrine produced a fall in the vitamin C content of normal rat adrenal cortex similar to that provoked by certain injurious agents, but did not when given three days following hypophysectomy. A similar result was obtained by Sayers and Sayers (7) with experimental hemorrhage. From these and other studies, it would seem that the adrenal cortex, presumably by way of the pituitary, is provoked to hyperactivity by many kinds of harmful stimuli, a response which is now believed to be an important part of the systemic reaction to injury, or indeed of damage or stress of other kinds including "psychic trauma."

From the purely clinical point of view, many studies have revealed the nature and extent of the systemic nonspecific effects of injury, particularly of planned operations. Perhaps the earliest was initiated by a series of reports by Leriche, based on what he called "La Maladie Postoperatoire." This early work was summarized in a monograph with that title (8) and by a more recent report (9). During World War II, many biochemical and metabolic studies were made in injured soldiers (10, 11, 12). Extensive metabolic studies of civilian patients during postoperative convalescence were reported by Cole and his co-workers (13), which has added much to our knowledge. A brief study of surgical convalescence by Elman and Akin (14) contains observations regarding nutrition, psychogenic factors, and physical factors. More recently, in a monograph containing excellent data on many carefully observed postoperative patients, including volunteer controls, Moore and Ball (15) have continued the work and stimulated further interest in this field.

The most recent and extensive clinical study of the systemic effects of injury was that of a surgical research team set up by the United States Army during the latter part of the Korean conflict. The extensive findings have been summarized in four volumes from the Walter Reed Army Medical Center (16). Much of these data will be used in the following discussion.

PITUITARY-ADRENAL REACTION

The concept of a pituitary-adrenal reaction as a nonspecific, systemic response to injury is recent, stimulated largely during the past decade by epoch-making chemical research on the hormones of the two glands. This new field has already yielded potent therapeutic agents and many intriguing ideas, which may completely alter our concept of disease and of therapy. In the following discussion, an attempt will be made to summarize the bare essentials of this vast amount of knowledge as it applies to the treatment of the injured, realizing that much is unknown and that even what is supposedly known will change as in-

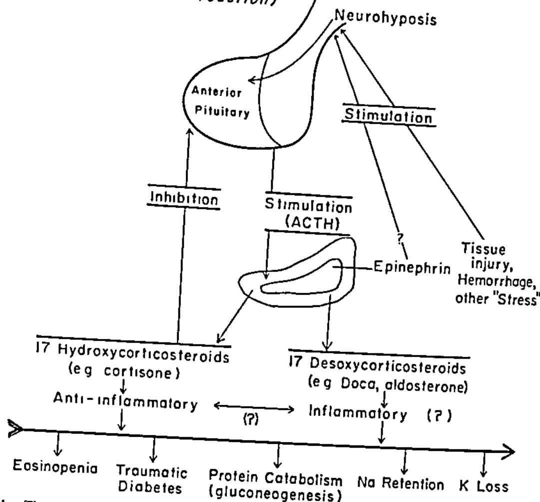


Fig. 1. The pituitary-adrenal reaction. Presumed pathways of the "alarm reaction" diagrammatically represented. The balanced inflammatory-anti-inflammatory action of the groups of corticoids is largely theoretical or speculative at the present time. The variations in the physiologic action of the two groups of corticoids are arbitrarily listed at the bottom. The heavy arrow is supposed to indicate quite grossly the relative action of the two groups.

creasing contemporary research adds more information. This tentative nature of our knowledge applies especially to the probable pathways of the pituitary-adrenal reaction to injury as illustrated in Figure 1.

History. The vital function of the adrenal glands was known to Brown-Sequard and his followers when it was noted that bilateral adrenalectomy was incompatible with life for more than a few days or weeks in mammals, for only a few hours in birds. That the adrenals maintain life by secreting essential hormones was shown by Rogoff and Steward, Swingle and Hartmann, and others when lipid and aqueous extracts of the glands prolonged the life of adrenalectomized animals and, in fact, improved the symptoms in patients whose adrenals had been destroyed as in Addison's disease. But the greatest advance came when the individual hormones of the adrenal cortex began to be isolated, identified, and even synthesized. Among the many investigators in this field, three chemists, working simultaneously in different parts of the world during the period preceding World War II, were largely responsible for the beginning of this new knowledge. They are Kendall, Reichstein, and Wintersteiner; the first two were awarded the Nobel prize for their discoveries.

Reichstein, a Swiss organic chemist, having gathered tons of beef adrenals, made a sys-

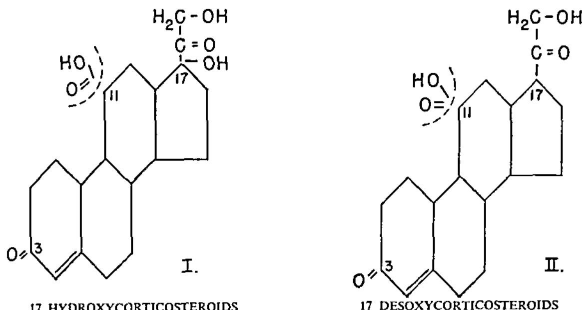


Fig. 2. Adrenocortical hormones. On the left is represented the group of steroids notable for its anti-inflammatory action, influence on carbohydrates and protein metabolism, and beneficial effect in shock due to adrenocortical insufficiency. By contrast, on the right is the group notable for its influence on salt metabolism, hence sometimes called mineral corticoids.

Group I. General formula for free 17-hydroxycorticosteroids, often shortened to 17-hydroxycorticoids or abbreviated as 17-OHCS. Note the OH radical at the 17 position, characteristic of this group. The grouping at the 11 position is of special significance; the three possibilities are illustrated. Using the Kendall classification, Compound E or cortiscone has a keto (oxygen) radical at this point, Compound F or hydrocortisone an hydroxy radical, Compound S has nothing (desoxy). The latter has little clinical importance. This group of corticoids are best measured chemically (at the present time) by the Porter-Silber (P-S) reaction.

Group II. General formula for free 17-desoxycorticosteroids, often shortened to 17-desoxycorticoids or abbreviated as 17-desoxy-CS. Note that they differ from 17-OHCS only in the absence of the OH radical at the 17 position, hence the name. The three variations at the 11 position are the same as above, the Compounds being A, B, and D respectively. Only Compound D is important clinically, with no oxygen (desoxy) at the 11 position. It is well known as DOC, the abbreviation of desoxycorticosteroid, or as DOCA, the acetate salt. The 17-desoxycorticosteroids are not clinically measurable as such, but can be determined by subtracting the P-S value from the Mader-Buck reaction which measures both groups. Note in both groups the keto (oxygen) radical at the 3 position. This, with the double bond adjacent to it (called D4), is found in all biologically active free steroids.

tematic study of adrenocortical hormones which he isolated therefrom (17). He was able to identify 28, all 4-ring steroids, 24 with 21 carbon atoms, three with 19, and one with 18. Many of them have little practical interest and may perhaps have been artefacts during the long chemical manipulations. In addition to the many steroids characteristic of the adrenal, progesterone and estrone were also found. According to present knowledge, the important adrenocortical steroids (or, more simply, corticoids) may be classified into two groups, all having 21 carbon atoms, the 20 and 21 carbons being in the form of a ketol chain —C=O—CH_2OH at the 17 position (Fig. 2). Group I has an OH at the 17 position and is called, collectively, 17-hydroxycorticosteroids (17-OHCS); Group II has no OH at this position and is called 17-desoxycorticosteroids (17-desoxy-CS). Each group comprises at least three specific compounds differing only in the 11 position which may carry either a keto (O =), an hydroxy (OH —), or a desoxy (nothing). Kendall (18) called the three compounds in Group I, Compounds E, F and S;* in Group II, Compounds A, B, and D, respectively (Table 1). It so happens that Compound E,

* Reichstein's identification.

TABLE 1. Adrenal Cortical Fraction

Group	Fractions	Chief Physiological Actions
I	17-Hydroxycorticosteroids E* Cortisone F Hydrocortisone S 11-Desoxy-17-hydroxycorticosterone Pregnisolon	These fractions produce the anti-inflammatory action in acute rheumatism and associated diseases. They increase the breakdown of tissue proteins to amino acids with resultant synthesis of glucose from the acids (gluconeogenesis). They result in the disappearance of eosinophils and lymphocytes Hydrocortisone is the chief fraction in the human and, having a greater water solubility, can be given intravenously.
II	17-Desoxycorticosteroids A Dehydrocorticosterone B Corticosterone D Desoxycorticosteroid (DOC) Aldosterone	These fractions result in the selective retention of water and sodium, and the selective excretion of potassium by the renal tubules. Aldosterone has a salt-retaining activity 10 times that of DOC.
	Androgen Estrogen Progesterone	Secondary sex characteristics

* This column represents Kendall's classification except for S which is from Reichstein.

popularly known as cortisone, and Compound D (dOC or dOCA, as the acetate) were easiest to synthesize and thus became available for clinical use long before the others. The newer ones are aldosterone, a 17-desoxy-CS, and the many derivatives of cortisone, a 17-OHCS, which will be discussed in more detail below.

The next chapter in the story of the pituitary-adrenal reaction was the identification and isolation of the adrenocorticotropic hormone, popularly known as ACTH from the many "tropic" hormones secreted by the anterior pituitary gland. The relation of the pituitary to the adrenal cortex had been known long before. Although hypophysectomy, unlike adrena'ectomy, was not incompatible with life, many of the effects of injury on the adrenal (e.g., hypertrophy, and depletion of vitamin C and cholesterol) did not occur after hypophysectomy. When it was finally found that ACTH stimulated the adrenal cortex, it was obvious that adrenocortical function was normally controlled by the pituitary. The secretion of adrenocorticoids was later shown to inhibit adrenocortical activity by decreasing ACTH production, thus providing a self-regulatory reciprocal mechanism characteristic of the relation of many other endocrines with the pituitary.

Next in the history of pituitary-adrenal reaction was the development of the concept that it represented a normal response of the body to such harmful exogenous stimuli as tissue damage, psychic stress, or even pronounced changes in environment. As described by Selye in 1947, the pituitary-adrenal reaction (5) represented a "call to arms"; hence the term "alarm reaction." This response, of course, was assumed to be beneficial, enabling the body to better resist the deleterious effects of injury. The pathway was through stimulation of the pituitary which, via ACTH, increased the output of adrenocorticoids. These corticoids themselves are known to provoke metabolic and other changes in the peripheral tissues similar to those observed following injury. Thus the metabolic changes following injury were assumed to be the result of, and indeed were called, the "alarm reaction." That this reaction was beneficial seemed obvious and was, of course, supported by the old observation that hypophysectomized or adrenalectomized animals, even when they remained alive, could not withstand the effects of even slight trauma or changes in environmental temperature unless protected by substitution endocrine therapy. This is also true of patients with Addison's disease. It is important

to emphasize, however, that the Addisonian patient may have no symptoms whatever while in a stable clinical state; his difficulty arises from the inability to resist even slight injury without developing serious peripheral shock and even death. All of this, however, still does not explain how the metabolic action of the corticoids helps protect the body against harmful exogenous stimuli. Little is really known of these metabolic changes, but some speculation may be mentioned.

That nature would provide a built-in mechanism for survival is axiomatic. Since survival demands a continuous supply of many substances for energy and other needs, it is clear that, in the absence of exogenous sources, it must use its own tissues. In an earlier stage of man's evolution, when the individual depended solely upon his own predatory and other activities for such exogenous nourishment, an accident or injury which resulted in enforced immobility made survival entirely dependent upon the extent to which his own tissues could supply these needs. Deprivation of intake, as in simple starvation, is compatible with survival for a variable period because these needs are met by protein and adipose tissue breakdown. Following injury, however, this simple process is apparently not rapid or extensive enough to meet the needs for existence and repair. It is not surprising, therefore, that the first and perhaps most important metabolic effect of injury to be observed was the increased breakdown of normal protein tissue. Such an action would, of course, yield a variety of metabolic, really nutritional, substances. The degree of this breakdown is measurable by the urinary excretion of nitrogen, which is known to rise two to four times above that in starvation alone. This phenomenon, often called the "catabolic response to injury," can also be provoked to some extent by both ACTH and cortisone. A more frequent name given to this phenomenon is gluconeogenesis, by which is meant the formation of glucose from tissue protein. It should be emphasized, however, that tissue protein breakdown yields more than amino acids which, on further breakdown, form glucose. Other substances are undoubtedly released which are also required for survival in the absence of any exogenous intake. On the other hand, there is little evidence that adipose tissue breakdown, which yields only energy, is increased during the alarm reaction. It is likely, however, that the mechanism for the formation of glucose is the most important action. This mechanism extends and augments the old and well-known release of glucose from hepatic glycogen following the increased secretion of epinephrine which, as shown by Cannon (4) just before the days of ACTH and cortisone, was part of the response to stress. Epinephrine provokes many other systemic effects now included in the alarm reaction. Since epinephrine is also secreted by the adrenal medulla, we seem to have traveled a sort of scientific circle, embracing a period of about two decades. This represents only a small segment of the vast amount of information which has accumulated during this time regarding the pituitary-adrenal reaction. Moreover, we are still in the dark as to the beneficial effects of the metabolic changes other than gluconeogenesis.

Because injection of cortisone and ACTH can, in the intact subject, provoke many of the metabolic results of injury, it is generally assumed that these metabolic disturbances are due to the peripheral action of the increased output of corticoid. This assumption, though widely held, must now be modified on the basis of recent observations made on bilaterally adrenalectomized patients maintained in a relatively normal clinical state with cortisone (19). Subsequent elective operations on these patients were found to be accompanied by the same metabolic changes as those produced by similar procedures in patients with intact adrenals. This would seem to indicate that the metabolic changes after operation may be primarily peripheral; i.e., they are the effects of operative tissue damage and anesthesia on the circulating corticoids, and not necessarily a manifestation only of increased adrenocortical secretion. While the increased secretion of pituitary and adrenal hormones is unquestioned, it may be that this action is merely secondary and regulatory. In any event, more study is needed of the effects of the peripheral tissues themselves on the metabolic conversion, reduction, and conjugation which the corticoids undergo not only under normal but especially in post-traumatic states. The greater influence

of the peripheral over the central changes is also suggested by observations on the anti-inflammatory action of the corticoids as discussed below.

The attempt to paint a simple picture of the alarm reaction also overlooks the fact that different steroids are secreted by the adrenal cortex (Table 1). Although it is true that hydrocortisone in the plasma, in man at least, is the most important member of the 17-OHCS group, there are various members of the 17-desoxy-CS group to be considered. Not only is the action of the latter different from that of the former, but each responds differently to the stimulus of injury and ACTH. For example, there is much evidence that the 17-desoxy-CS group may not even be under pituitary control and may have no balanced relationship with the secretion of ACTH, as is the case with 17-OHCS. Moreover, little is known of the extent to which the steroids may undergo conversion, one to the other, or be made inactive in various ways. Finally, it is already known that the physiologic effect of these hormones is certainly influenced by differences in their threshold of activity. For example, a large dose may produce an entirely different effect than a small one. This raises the question of whether the effect is really pharmacologic or physiologic. In actual practice, as much as 300 mg. of cortisone have been given per day—about ten times the amount normally produced, which rarely exceeds 30 mg. per day in an adult. Is the effect produced, therefore, due to the steroid itself, to its action in inhibiting pituitary function, or even to producing adrenocortical atrophy? Moreover, the length of time during which the hormone is administered is important. A very small dose of ACTH infused intravenously over a longer period will be a much more effective adrenocortical stimulant than a large dose administered during a short period of time.

Despite these factors, an attempt will be made to summarize present knowledge of this complicated pituitary-adrenal reaction under three headings, representing a somewhat arbitrary classification: (1) the *physiologic action* of the known corticoids; (2) the *changes in adrenocortical secretion* of these steroids as a result of trauma; and (3) the newest studies in the field, the *metabolic changes in the adrenocorticoids* once they leave the adrenal vein and enter the systemic circulation not only under normal but also under abnormal conditions of stress of various kinds, particularly operation or injury.

1. Physiologic Action of the Corticoids. The so-called *anti-inflammatory action* of cortisone and hydrocortisone and their derivatives is perhaps the most interesting of the physiologic actions of the adrenocortical steroids, and the one which first brought them to worldwide attention by showing their dramatic therapeutic application. This anti-inflammatory action was first noted experimentally by Selye (5), and aroused universal acclaim when cortisone was found to have a dramatic beneficial effect on the pain and the local inflammatory signs of rheumatoid arthritis. It is curious that, despite the increasing use of these steroids in many other conditions, the therapeutic pendulum in rheumatoid arthritis is now swinging back to the precortisone methods. It was soon found that this anti-inflammatory action was a local one. Indeed, dramatic benefits often followed when hydrocortisone was injected locally into inflamed tendons, joints, and bursae. Systemic effects were presumably responsible when a beneficial anti-inflammatory action was later found in a variety of conditions including hepatitis and thyroiditis. This systemic action was also supposed to explain the action of cortisone in certain specific bacterial inflammations, as tuberculous meningitis, pneumonia, and peritonitis. Although the effects were thought to be beneficial by greatly reducing the severe systemic manifestations, it was not clear whether this action lowered the response of the body to the invading agent, or suppressed the peripheral effects of the infection. Lowering of the body response would, of course, be ultimately harmful in reducing resistance. Present thinking, however, seems to point to the peripheral and the inflammatory action even when the steroid is given systemically. It might be compared to the use of antibiotics in the prophylaxis of infection of open wounds, in which the local effect was better subserved by letting the agents reach the injured tissues from the body side.

The local anti-inflammatory action of cortisone has been extensively studied by a

variety of technics. It seems generally agreed that this action consists of a decrease in the permeability of the inflamed capillaries and an increase in digestion and phagocytosis of exudate. This would certainly explain its local action in decreasing peritoneal adhesions and helping dissolve exudate in tuberculous meningitis, and even perhaps in combating anaphylactic shock. In anaphylactic shock, the increase in capillary permeability seems one of the decisive mechanisms, similar indeed to the local action of histamine. The lifesaving action of cortisone as a presumed anti-inflammatory agent is therefore thought to be that of counteracting this increase in capillary permeability.

The anti-inflammatory action of the corticoids is, of course, exerted to a pronounced degree only by the 17-OHCS group and not by the 17-desoxy-CS group. An intriguing theory was propounded by Selye, who felt that there was a reciprocal and balanced action between the two groups, one inflammatory and the other anti-inflammatory. Unfortunately for this idea, it is not supported by adequate evidence, at least as far as the presumed inflammatory action of the 17-desoxy-CS is concerned. It is true that, experimentally, DOCA can be made to produce or to aggravate inflammation, but only under very rigid and fixed experimental conditions. What appears closer to the truth is that, in general, each of the corticoids possesses this inflammatory action to a negligible, slight, or great degree, a variation which is characteristic of many of their other physiologic actions. Aldosterone, for example, has little anti-inflammatory action but pronounced salt effects. Most of the recent therapeutic advances have emerged from the synthesis of steroids which possess more anti-inflammatory action and less salt action than cortisone. For example, by introducing a double bond between carbons 1 and 2 in hydrocortisone, a substance called pregnisolon is produced which has ten to twenty times the anti-inflammatory action without alterations in its other effects. The anti-inflammatory action of the corticoids represents but one of their many physiologic actions.

The various corticoids produce *metabolic changes* which influence the behavior of water, salt, carbohydrate, and protein. As already mentioned, the various steroids, in the intact subject, produce these actions in varying degrees. The change in *protein metabolism* has already been discussed in terms of gluconeogenesis; a quality which is possessed to a marked degree by hydrocortisone, little or not at all by DOCA. The influence of the corticoids on *carbohydrate metabolism* is partly due to the release of glucose from tissue protein breakdown. But the effect is probably far greater than this, as first shown experimentally in 1934 by Long and Lukens (6), who showed that adrenalectomy alleviated many of the consequences of pancreatectomy. Cortisone, when given to animals, is diabetogenic, producing both hyperglycemia and glycosuria. This appears to be, at least partially, responsible for the so-called "traumatic diabetes," which has been observed after operation and injury (16) (Fig. 3), and which will be mentioned later. Recently, adrenalectomy has proved beneficial in Kimmelsteil-Wilson's disease, a serious and usually fatal complication of juvenile diabetes.

Water and salt metabolism is greatly influenced by the corticoids which, in a normal subject, will cause retention of water and sodium and an increase in the output of potassium—phenomena that are also normal metabolic effects of injury. The purpose of this reaction is not known, nor is the mechanism clearly understood, although it is probably mediated through changes in renal function. There is a possibility, however, that these changes may be the result of alterations in cell permeability, mentioned above as apparently being one of the mechanisms of the anti-inflammatory action. The salt action is possessed to the greatest degree by the 17-desoxy-CS, especially aldosterone. The group is therefore often called mineral corticoids. The salt action is possessed only slightly by the 17-OHCS which, by contrast, are often referred to as glucocorticoids. Aldosterone has a salt-retaining activity ten times greater than DOCA, and has no influence on carbohydrate metabolism or on the eosinophils, which is discussed below. Aldosterone is also a naturally occurring steroid, having been found in normal blood and urine. It differs chemically from DOCA only in the nature of its carbon 18 position, which has an aldehyde group, CHO instead of CH_3 as in DOCA.

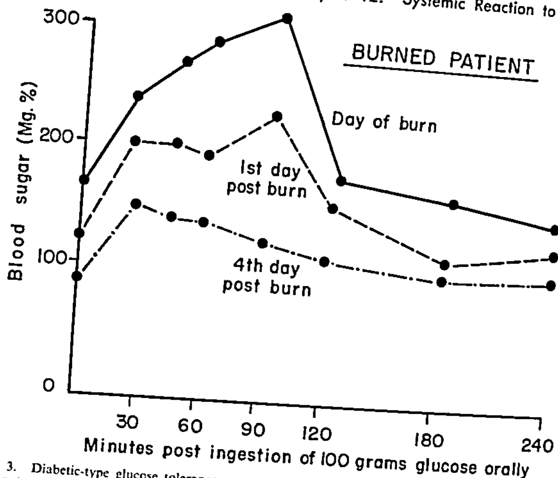


Fig. 3. Diabetic-type glucose tolerance curve following trauma. The hydroxycorticosteroids (Group I) are antagonistic to insulin since they increase the production of glucose (gluconeogenesis). A transient pseudodiabetic curve results.

Hyponatremia, during the post-traumatic and postoperative period, may also be due to the action of the mineral corticoids, although this is not certain. This finding does not appear to be due to water intoxication, as discussed elsewhere, nor to a salt deficiency. This phenomenon of hyponatremia is remarkable because it coincides with the positive sodium balance which follows sodium retention—due presumably to the increased secretion of aldosterone. The evidence of post-traumatic hyponatremia comes from several sources. One of the most convincing is a study of 25 Korean War battle casualties by Howard and his associates (16), 17 of whom showed a drop from the normal concentration of 140 mEq. per liter to levels of 125 mEq. per liter or lower, one as low as 109 mEq. per liter, during the first few days after injury. The plasma potassium was occasionally elevated, especially with the onset of oliguria. In a few instances the rise in potassium and the fall in sodium were strikingly coincidental. Postoperative hyponatremia is especially prone in patients with cardiac and hepatic disease and after valvulotomy for mitral stenosis.

Although there is no immediate explanation of this fall of plasma sodium, one cannot overlook the possibility of a change in cell permeability. The great mass of muscle, and the hepatic, renal, and other cells, with their high intracellular concentration of potassium enclosed in a vast bath of fluid containing largely sodium ions, might readily exchange sodium for potassium. Such an explanation awaits further study, although it has been definitely demonstrated to occur following injury to cardiac muscle. In the meantime, several therapeutic implications can be emphasized. First, it is possible that the administration of sodium chloride in isotonic or hypertonic solution for the correction of unexplained post-traumatic hyponatremia may

lead to more harm than good when the low plasma level is not due to a deficiency. Second, intravenous alcohol (20) and mannitol (21) have been recommended to restore this disturbance in salt metabolism on the basis of evidence which deserves further clinical trial.

The *circulatory changes* under the control of the adrenal cortex are shown by the fact *that shock often follows atrophy or inactivity* of the adrenal cortex. This is an old observation and is apparently associated with the physiologic action of the 17-OHCS rather than the 17-desoxy-CS. The mechanism is poorly understood. One explanation is the possible influence of the corticoids on the vasomotor tone of the arterioles or capillaries. In view of the established action of cortisone on capillary permeability, its action may be due to a conservation of blood volume by halting the loss of fluid through capillaries throughout the body, as mentioned above. Improvement in the peripheral circulation following the intravenous infusion of hydrocortisone has been indicated in certain cases of shock after prolonged operations (22). This finding has not been substantiated in experimental animals in hemorrhagic shock (23). It has been particularly observed in *poor-risk tuberculous patients after pulmonary resection* (24). Shock on sudden withdrawal of cortisone after long-continued therapy therewith, as mentioned below, is presumably due to adrenocortical atrophy and likewise responds to cortisone therapy.

The *lymphoid changes* produced by adrenocortical steroids were first discovered by Dougherty and White (25), who found that adrenocortical stimulation with ACTH was followed by a dissolution of lymphocytes in

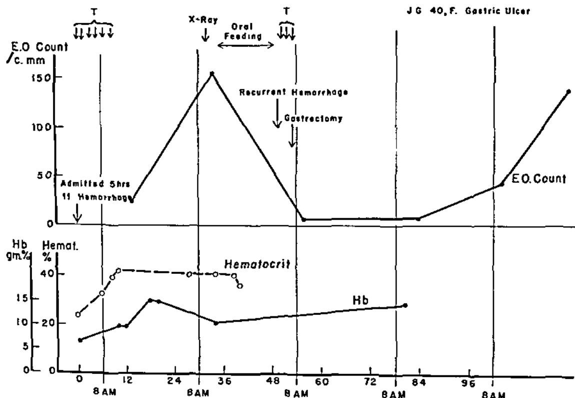


Fig. 4. Recurrent massive gastrointestinal hemorrhage. The patient was a 40-year-old housewife who was in shock when first seen in the receiving room following a massive hematemesis. There was good response to blood transfusion, although it is probable that the amount given (3 liters) was somewhat excessive. A barium meal revealed a gastric ulcer and she was started on oral feeding. The next morning she had a recurrent hematemesis and was promptly taken to the operating room and a gastric resection including the ulcer performed. Recovery and subsequent course were uneventful. Note the response of the eosinophils to each stress. This is normal and also occurs after infusions of ACTH, as shown in Figure 5.

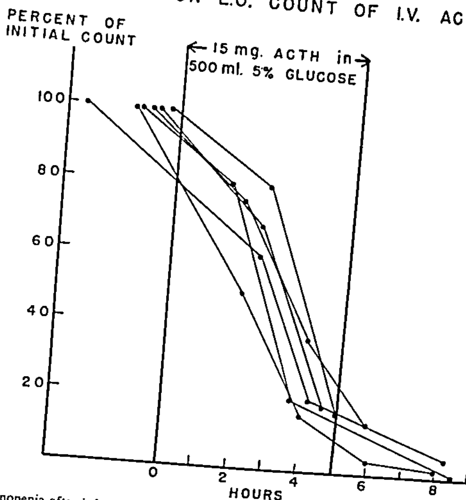


Fig. 5. Eosinopenia after infusion of ACTH. The above curves are from six relatively normal human subjects. Note that it took about eight hours for the eosinophils to disappear, even after a five-hour infusion. This effect is not achieved unless the infusion is continued for at least four hours, regardless of the dose employed. It is likely indeed that the same curves would have been possible with a dose of 5 mg. or less.

the blood and in the lymph nodes. The purpose of this reaction is unknown, but it may be concerned with producing an increase in the resistance of the body to infection inasmuch as this reaction is accompanied by the release of gamma globulin and perhaps other plasma proteins. Dougherty and Noble (26) found a pronounced fall in lymphocyte count in rats following a single trauma, the value returning to normal in 48 hours—an observation soon confirmed clinically. Later it was observed that this phenomenon was shared by the eosinophils (Fig. 4) which, being much easier to count, are now commonly employed to measure pituitary-adrenal response to trauma. Eosinopenia also follows ACTH infusions of more than 4 hours (Fig. 5) and cortisone injections. The historical development of this laboratory test is of considerable interest.

Schilling (27), as early as 1929, pointed out that while trauma and infection provoked an increase in the total leukocyte count (leukocytosis), the increase was solely in the neutrophils, a change called a "shift to the left." But he also found that the eosinophils did not increase and, indeed, tended to diminish or disappear during the acute phase, returning to normal or higher levels upon recovery. Even earlier than this, in 1917, Krumbhaar (28), while experimenting with guinea pigs subjected to various injuries, noted that the eosinophils tended to disappear despite the fact that the total number of white cells rose. Neither of these observers knew of the possible influence and significance of

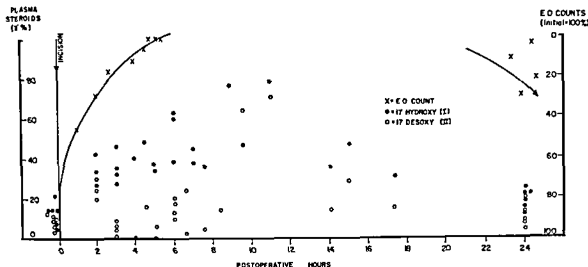


Fig. 6. Effect of operation on eosinophil count and on plasma steroid concentration. The eosinophil count (scale on the right) drops sharply during the first four hours after the beginning of operation. At the end of 24 hours, the cells are beginning to reappear. The concentration of the 17-hydroxycorticosteroids in the plasma increased rapidly during the first few hours. The concentration of the 17-desoxycorticosteroids did not consistently increase; indeed, it fell to zero in several patients.

these findings on the activity of the adrenal cortex. However, changes in the blood picture following the alarm reaction were described in 1939 by Dalton and Selye (29). More recent observations have shown that the eosinophils actually disappear from the peripheral blood not only after operation (Fig. 6) but also following the slow infusion either of ACTH or of cortisone, and even of epinephrine. Steroids of the cortisone group (17-OHCS) are far more active in this respect than the others. Nevertheless, eosinopenia does not always follow trauma, especially when local anesthesia is employed (30).

Other blood changes are known to occur after operation or trauma and may perhaps also be in part due to the primary or secondary effect of corticoids, although the evidence at present is insufficient to draw such a conclusion. These changes, which include anemia and increased blood coagulability, are discussed later in this chapter. Other outlying effects of injury, also described later, may be part of the pituitary-adrenal reaction, although the evidence is still slight.

2. Changes in Adrenocortical Secretion. The evidence is incontrovertible that there is an increased secretion of corticoids following stress as well as following injection of ACTH. This conclusion is based upon results of steroid analyses of adrenal as well as peripheral venous blood and of urine, from both animals and man. Of the many methods of corticoid analysis, the most valuable are based upon meticulous extraction, hydrolysis, column chromatography, and various colorimetric reactions. Confirmatory data have also been obtained by paper chromatography. Biologic methods were the earliest used. These were based upon the amount of hepatic glycogen which was deposited in adrenalectomized animals after the injection of urinary excretion of cortisone or cortisonelike materials, which were capable of inducing gluconeogenesis. These substances have often been called glucocorticoids or cortin. Biologic methods have now been replaced by chemical methods which are, in general, more precise and easier to perform.

In human peripheral blood, the concentration of 17-OHCS is about the same as that of 17-desoxy-CS or about 10 μg. per cent. Analysis of individual steroids shows that Compounds B and F represent the two groups respectively and that the former is present in half the concentration of the latter. Analysis of blood from the adrenal vein usually shows a greater difference between F and B, in favor

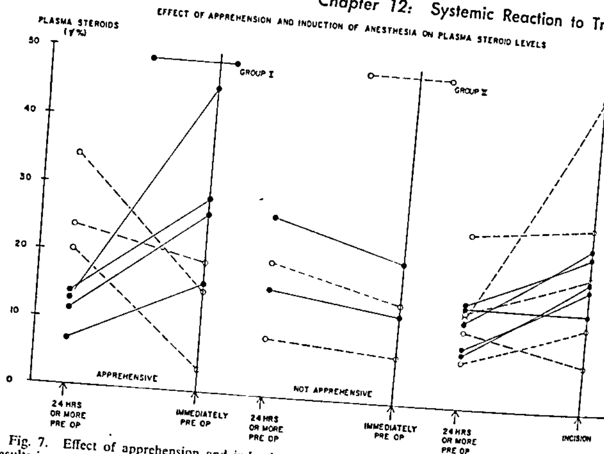


Fig. 7. Effect of apprehension and induction of anesthesia on plasma steroid levels. Apprehension results in a marked rise in the plasma concentration of 17-hydroxycorticosteroids (Group I) but not of the 17-desoxycorticosteroids (Group II). Induction of anesthesia had an additive effect, resulting in a rise in the concentration of both fractions.

of the former. Unfortunately, samples of adrenalvenous blood are often admixed with vena caval and renal blood. Moreover, the specimens usually are from patients suffering terminal mammary cancer, and thus may not be representative of that in the normal person. It is generally agreed, however, that, in man, Compound F or hydrocortisone is the main representative of the 17-OHCS in the peripheral blood.

Increases of corticoid in the peripheral blood following operation were first noted by Nelson and Samuels (31), who measured the 17-OHCS by a modified Porter-Silber reaction during 6 to 10 postoperative hours. Postoperative studies for longer periods, up to 72 hours, were made by Elman and his coworkers (32), the data for the first 24 hours being shown in Figure 6. These observations are of special interest also because they include determinations of the 17-desoxy-CS which did not share in the increase shown by 17-OHCS, but actually fell to zero in some cases. As already mentioned above, there is other evidence that 17-desoxy-CS groups of corticoids were not under pituitary control (Fig. 7). No differences were noted in relation to age or sex, but the less severe operations were followed by only slight or no elevation in the blood level of 17-OHCS.

As far as urine studies are concerned, mention should first be made of the tremendous literature on the determination of the 17-ketosteroids. It is now known that this group, as measured by the Zimmerman reaction (33), contains only 19 carbon atom steroids and really represents a sort of wastebasket containing not only metabolites of the corticoids but also such other steroids as progesterone and testosterone. Moreover, there is so much confusion as to the significance of these measurements as a measure of adrenocortical activity that no attempt will be made to summarize these data. In general, the 17-ketosteroid studies have shown little or conflicting changes after operation, as illus-

TABLE 2. The Effect of Gastrectomy on Urinary Steroid Excretion (mg. per 24 hours)

	Preoperative Days		Postoperative Days				
	−2	−1	1	2	3	4	5
17-Ketosteroids							
Patient 1	11.0	7.0	18.0	12.0	—	12.0	10.0
Patient 2	14.0	10.0	11.0	9.0	13.0	5.0	—
17-Hydroxycorticosteroids*							
Patient 1	4.4	3.7	29.0	11.8	—	4.3	3.2
Patient 2	2.4	3.4	28.7	10.6	4.4	3.3	—

* In five normal subjects, the 24-hour excretion rose during the day of a four-hour intravenous infusion of ACTH (25 mg.) from 2.8 to 8.2, from 3.7 to 16.0, from 2.5 to 28.0, from 2.7 to 6.7, and from 9.0 to 12.0 mg.

trated in Table 2. Many of the unexplained variations are due to differences in the method of hydrolysis. Extracts of urine must usually be hydrolyzed because the urine contains very few free steroids, most of them being present as glucuronic acid or sulfuric acid conjugates. Thus, analysis of total corticoids depends upon adequate and careful hydrolysis. When mineral acids are used instead of glucuronidase, some loss of steroids occurs. On the other hand, a few of the reports contain data based upon analysis of nonhydrolyzed extracts, thus representing free steroids which, of course, would give much lower figures.

Measurement of 21 carbon corticoids in the urine may be expected to give more exact information regarding changes in adrenocorticoid activity, particularly when the Porter-Silber color reaction is used. Because of the greater specificity, this reaction is being used more and more, even though it measures only the 17-OHCS. Comparison of data from different sources may still present difficulties due to the influence of varying methods of hydrolysis, as mentioned above. In many studies, moreover, the so-called formaldehydogenic method which is relatively nonspecific, is used, even though it is supposed to measure both 17-OHCS as well as 17-desoxy-CS. In the following summary an attempt will be made to include significant data on the urinary corticoid excretion both in the normal and after stress.

In normal individuals, Venning and Browne (34), using a biologic method, found that male subjects excrete twice as much cortin as females, an observation which was recently confirmed by Reddy, Jenkins, and Thorn (35), who used the Porter-Silber method. As to age, McFarlane and associates (36), using the same method, found no difference in the normal excretion of urinary corticoids at different ages. Following an intravenous infusion of ACTH, however, these observers noted a greater increase in urinary output in the young than in older subjects. By contrast, Dobriner (37), using even more careful biochemical methods, found that individual variations followed the intravenous infusion of ACTH in old and young subjects, but not in relationship to their age.

Following operation or injury, there is general agreement on an increased urinary excretion of corticoids, although variations in degree are fairly wide. For example, Venning and Browne found as much as ten times the normal excretion of cortin in the urine of three severely burned patients, an increment which persisted for three weeks before returning to the base level. Elman and his co-workers obtained similar, but less pronounced, findings using a refined method of hydrolysis and the Porter-Silber reaction. In females after hysterectomy, the rise was much less pronounced. In the extensive studies carried out during the Korean conflict (16, 38), using a modified formaldehydogenic method, the urinary excretion often rose to five to fifteen times the normal on the first or second post-traumatic day.

3. Metabolic Changes in Adrenocorticoids. From a variety of studies, including analyses of adrenal venous blood, peripheral

blood, and urine, it is now known that a number of changes occur in the free, biologically active, adrenal cortical steroids after they leave the adrenal vein and are carried to the various tissues of the body. *Many of these* changes are known, others still unknown. Their importance has already been suggested by the observations made in adrenalectomized patients.

Conjugation of the steroids with glucuronic acid and, undoubtedly, with one or more of the organic acids of the body is perhaps one of the best known. This change probably occurs in the liver and renders the steroid biologically inactive. This phenomenon probably explains the early clinical observation that arthritis improved whenever a patient developed jaundice, presumably because more free steroids remained in the peripheral blood. Conjugation and reduction, with or without conjugation, may occur in other tissues, perhaps even in malignant tissue. Conversely, some of these steroids may have an influence on the behavior of malignant cells. The fact that the clinical regression of tumor has been observed in some patients with extensive breast and prostatic cancer following adrenalectomy and hypophysectomy suggests such a relationship.

Changes other than conjugation and reduction may occur which also render some of the free steroids inactive. Reduction may occur without conjugation at the 31 position from keto- to hydroxy- with saturation of the 4Δ double bond as well. Other conversions are possible and a few probable. A change from DOCA to pregnanediol has apparently been demonstrated both in animals and in man. Other changes even from the 17-OHCS to 17-desoxy-CS may occur, although definite proof is lacking.

The *renal clearance of adrenal corticoids* is also of importance in their peripheral behavior and therefore in evaluating the pituitary adrenal reaction. Thus the excretion rate for the various steroids, when increased or decreased, will play an obvious part in their blood levels and thus on the degree of their physiologic actions. An analogy may be drawn with the effectiveness of such drugs as chemotherapeutic agents normally excreted in the urine. The blood levels of penicillin, for example, are always higher in anuria.

THERAPY IN THE ALARM REACTION

Once ACTH and cortisone became available as active agents, it was natural that attempts would be made to extend their therapeutic application to surgical patients. At first it was believed that giving ACTH after operation or injury would aid nature's response; the argument being that, since the pituitary-adrenal reaction is a normal mechanism, making it more intense might increase its effectiveness. It soon became apparent that the matter was not quite so simple, and more knowledge was necessary. One might say, in general, that therapy in regard to the alarm reaction might take one of two directions. 1. An attempt might be made to decrease the intensity of the response should it become excessive; 2. It must be determined whether there is a need for supplying missing hormones when the normal response is absent or inadequate. Such an approach obviously must take into account the wide variations in *the spontaneous reaction to trauma. In the* following discussion, therefore, three types of response to trauma will be described, based largely on clinical considerations. In some instances there seems to be a good correlation with these clinical changes and differences in the pituitary-adrenal reaction.

In Group I are included young, healthy, well-nourished males, in whom severe injury is usually followed by extreme prostration, moderate fever, and huge losses of tissue protein; changes which undoubtedly mean an intense adrenocortical response. The question may be raised: Would a less intense response be clinically desirable? A positive answer is suggested by the following experience, during the Korean conflict. A soldier, who suffered extensive injury and required radical surgical procedures, showed only a moderate systemic reaction, little hepatic insufficiency, and remarkably good postoperative healing. Study of the urinary output of corticoid showed scarcely any increase, indicating a rather moderate pituitary-adrenal reaction. This correlation of a favorable clinical response to trauma with a modest pituitary-adrenal reaction is also supported by the fact that females in whom the alarm reaction is less severe than in males (see above), react much more violently and indeed recover more rapidly after

operation or injury than the male, other things being equal. One might speculate regarding this difference by postulating that the male, having been through the centuries more subject to accidental trauma, has developed a more intense pituitary-adrenal response than the female. In any case, should it prove true that a less intense pituitary-adrenal reaction would be clinically desirable, attempts to lower the intensity of the response in healthy males would seem justified, at least within certain limits and by means still unknown.

Group II comprises well-nourished patients of advanced years, and females in general. It is an old clinical observation that older patients, somewhat as females, react less violently and seem less prostrated than younger individuals, even after severe operation. While it is true that such older patients are unable to withstand infection, shock, and other complications as well as more youthful individuals, their postoperative convalescence in the absence of complications is often much smoother than that of younger individuals. Should this desirable objective be a manifestation of a less intense pituitary reaction, it would add to the indications mentioned above for therapeutic means of reducing the intensity of the alarm reaction in young male adults. The idea of using a preliminary infusion of ACTH several days before an elective operation, to achieve such an objective, has been advanced (39), but lacks proof.

Group III comprises patients in poor general condition, who are poor risks for any significant trauma. The question arises, Is this unfavorable response to trauma related to impaired or absent pituitary-adrenal reaction? It is, of course, well known that in Addison's disease any harmful stimulus threatens life. This is also true of patients in whom adrenal atrophy follows the withdrawal of cortisone after prolonged therapy therewith. Cachexia is also known to be associated with a decrease in pituitary function and thus with a suppression of ovarian, testicular, and adrenocortical activity. Underactivity of the adrenal may also occasionally occur in postoperative patients who go into unexplained shock, a state which responds dramatically to cortisone or hydrocortisone (22). The favorable response of patients severely ill with thyroiditis and hepatitis to cortisone therapy may also be due to a similar need for this steroid, although the anti-inflammatory effect of cortisone may be the explanation. In any case, further observations will be necessary to determine which is the cause. The eosinophil count is an easy test and should perhaps be used more often despite its pitfalls. For example, a drop to zero after operation, followed by a rise within 24 to 48 hours is normal, whereas failure to remain at zero or failure to fall again in the face of severe complications might in itself indicate sudden adrenocortical impairment and the therapeutic need for adrenocortical steroids. The main pitfall in the interpretation of the eosinophil count is its failure to fall, particularly when spinal anesthesia is used. In any case, the indications for supplying steroids or ACTH would seem direct and logical in this group of patients. What is needed, of course, is a better clinical method of determining the inadequacy or failure of the alarm reaction.

In *summary*, one may say that the therapeutic application of knowledge of the alarm reaction to surgical patients awaits further information. Although it is obvious that the integrity of the pituitary and adrenal glands is essential for survival, and that an adequate response by these glands is probably also necessary for the body's successful resistance to harmful stimuli, this does not mean that the most intense response is necesarily the most beneficial to the patient. An excessive alarm reaction may, in fact, be detrimental and offers a therapeutic challenge for the future. More significant clinically and therapeutically, at the present time at least, are the many situations, some definite, others indefinite, when adrenocortical function is impaired or even absent, situations in which the use of ACTH and cortisone may be of direct clinical benefit.

Cortisone Therapy and Surgical Disease. The prolonged use of cortisone by patients with a variety of such chronic diseases as arthritis and asthma has a practical surgical aspect whenever these patients become subject to a surgical disease requiring either an elective operation, as cholecytitis, or an emergency operation, as acute appendicitis. In the latter case, it has been found that the steroids (like antibiotics) so greatly reduce the usual signs of peritoneal irritation that the diagnosis

blood, and urine, it is now known that a number of changes occur in the free, biologically active, adrenal cortical steroids after they leave the adrenal vein and are carried to the various tissues of the body. Many of these changes are known, others still unknown. Their importance has already been suggested by the observations made in *adrenalectomized* patients.

Conjugation of the *steroids* with glucuronic acid and, undoubtedly, with one or more of the organic acids of the body is perhaps one of the best known. This change probably occurs in the liver and renders the steroid biologically inactive. This phenomenon probably explains the early clinical observation that arthritis improved whenever a patient developed jaundice, presumably because more free steroids remained in the peripheral blood. Conjugation and reduction, with or without conjugation, may occur in other tissues, perhaps even in malignant tissue. Conversely, some of these steroids may have an influence on the behavior of malignant cells. The fact that the clinical regression of tumor has been observed in some patients with extensive breast and prostatic cancer following adrenalectomy and hypophysectomy suggests such a relationship.

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The renal clearance of adrenal corticoids is also of importance in their peripheral behavior and therefore in evaluating the pituitary adrenal reaction. Thus the excretion rate for the various steroids, when increased or decreased, will play an obvious part in their blood levels and thus on the degree of their physiologic actions. An analogy may be drawn with the effectiveness of such drugs as chemotherapeutic agents *normally excreted* in the urine. The blood levels of penicillin, for example, are always *higher* in anuria.

THERAPY IN THE ALARM REACTION

Once ACTH and cortisone became available as active agents, it was natural that attempts would be made to extend their therapeutic application to surgical patients. At first it was believed that giving ACTH after operation or injury would aid nature's response; the argument being that, since the pituitary-adrenal reaction is a normal mechanism, making it more intense might increase its effectiveness. It soon became apparent that the matter was not quite so simple, and more knowledge was necessary. One might say, in general, that therapy in regard to the alarm reaction might take one of two directions. 1. An attempt might be made to decrease the intensity of the response should it become excessive; 2. It must be determined whether there is a need for supplying missing hormones when the normal response is absent or inadequate. Such an approach obviously must take into account the wide variations in the spontaneous reaction to trauma. In the following discussion, therefore, three types of *response to trauma* will be described, based largely on clinical considerations. In some instances there seems to be a good correlation with these clinical changes and differences in the pituitary-adrenal reaction.

In Group I are included *young, healthy, well-nourished males, in whom severe injury is usually followed by extreme prostration, moderate fever, and huge losses of tissue protein;* changes which *undoubtedly mean an intense adrenocortical response.* The question *may be raised: Would a less intense response be clinically desirable? A positive answer is suggested by the following experience, during the Korean conflict. A soldier, who suffered extensive injury and required radical surgical procedures, showed only a moderate systemic reaction, little hepatic insufficiency, and remarkably good postoperative healing. Study of the urinary output of corticoid showed scarcely any increase, indicating a rather moderate pituitary-adrenal reaction.* This *correlation of a favorable clinical response to trauma with a modest pituitary-adrenal reaction is also supported by the fact that females in whom the alarm reaction is less severe than in males (see above), react much more violently and indeed recover more rapidly after*

sions, may also occur. From an extensive study of the war-wounded by Beecher (41), he concluded that the sensorium was influenced not so much by pain as by apprehension, fear of physical disability, concern as to the outcome of the injury, and other emotions. In a few instances, the emotional factors are favorable, in terms of relief resulting from being detached suddenly from danger, or unfavorable, in terms of the deaths of comrades by their sides or extensive injuries occurring next to them. In civilian injuries, some of these emotional factors also play a part though to a lesser extent. They are all part of the psychogenic factors of surgical diseases already mentioned, and discussed in detail elsewhere (43).

Sensorial changes may also be due to specific causes—for example, anoxia—which may follow peripheral circulatory impairment (shock), loss of blood, and so forth. Restlessness, such abnormal behavior as picking at the bed clothes, or frank apathy may occur. Occasionally, the patient in shock may be deeply obtunded although rarely is he comatose. Unconsciousness from shock usually means complete cessation of cerebral blood flow, consequently cardiac arrest and, of course, is incompatible with life for longer than four minutes. Infection, if severe, also produces a variety of sensorial disturbances which, when severe, are called "toxic psychosis." Renal impairment is also followed by mental changes well known in cases of uremia. Electrolyte disturbances which lead to changes in mental behavior have already been discussed.

Aside from the cerebrum itself, the peripheral nerves may also play a part in some of the nonspecific effects of trauma by initiating reflex changes such as vasospasm in peripheral arteries and even in the renal arteries. Much has been written of these peripheral effects and of the value of nerve block or even of sympathectomy in therapy.

2. The *liver* is frequently influenced by trauma beyond its anatomic boundaries. This is manifested by impaired function, rarely severe enough to produce jaundice (not due to increased hemolysis or biliary obstruction). Impaired hepatic function, if severe enough, is, of course, a threat to life itself insofar as the liver is an essential organ. Even moderate degrees of hepatic insufficiency are harmful by decreasing the resistance of the body to disease and injury. One of the functions of the liver deals with the peripheral metabolism of adrenocortical steroids and may, of itself, have a decisive influence, although little is known thereof at present. However, impaired hepatic function has been shown to lead to a decreased rate of steroid conjugation and thus to the accumulation of a larger amount of free steroids in the peripheral blood. Whether this is favorable or unfavorable to the body's defense against injury remains unknown. It is curious that, despite this mechanism, cortisone therapy has been reported as beneficial in hepatitis.

The evidence of hepatic impairment after injury is unquestioned but not extensive. Tagnon and associates (44) found abnormal bromsulphalein retention in 14 of 20 patients after operation. Keeton, Cole, and associates (45), using urobilinuria as their test, found hepatic impairment after inhalation but not after spinal anesthesia. The impaired function reached its maximum by the third postoperative day and was made worse by infection. During the Korean War, Scott, Olney, and Howard (46), found increases in the plasma total and indirect bilirubin immediately after injury, reaching a peak five times the normal six hours afterwards. The urine urobilinogen rose simultaneously in a few of the cases studied. Since the urobilinogen is normally manufactured from bilirubin excreted in the bile, it is not surprising that Galt and Hunter (47) found that an intestinal antiseptic (aureomycin) led to the appearance of bile and the disappearance of urobilinogen in the stool. It is therefore clear that urobilinogen measurements are probably of little or no significance as a measure of hepatic function in patients in whom such antibiotics have been used. The bromsulphalein retention in the above battle casualties was usually elevated on the first postoperative day and was most marked (as high as 42 per cent) in those in severe shock, especially those with abdominal wounds. Thymol turbidity remained unchanged, while cephalin flocculation was increased after injury. Plasma prothrombin activity was somewhat depressed following injury and transfusion of stored blood. The synthesis of fibrinogen was apparently unim-

may be completely missed. It has become clear, therefore, that acute appendicitis, perforated peptic ulcer, or similar surgical emergencies, in patients receiving these steroids, represent a real hazard. In such cases, it is important, of course, that the intake of these steroids be maintained should operation be carried out. This is equally true of elective operations, although here it may be more advisable to combat adrenal atrophy by gradual withdrawal of the drug and to operate later, when adrenocortical function has been restored to normal. This use of cortisone in infections has been discussed elsewhere.

A number of monographs are available dealing with the effects of stress on changes in the pituitary and adrenal function. A large, complete, and recent review is the report by Selye (39). The monographs by Hasner (40) and a recent brief summary by Zimmerman (33) are also suggested for further reading.

THE INFLUENCE OF THE WOUND

Certain systemic effects of trauma are due directly to the wound itself, most of them producing well-known reactions; for example, loss of blood leading to shock needs no further comment here and is discussed in detail in Chapter 13. The role of the wound as a portal of entry for systemic infection is also discussed elsewhere. The local pain, the degree of which is often greatly exaggerated, as shown in a study of war wounds by Beecher (41), does, nevertheless, act as a stimulus to the pituitary-adrenal or stress reaction, as already discussed. Of some historical interest is the "noci-association" theory of Crile (42) promulgated over forty years ago. Believing that harmful pain stimuli from the wound exerted remote deleterious effect, even in the deeply anesthetized patient, he blocked the area of the incision with novocain as a routine. Although this procedure is now seldom if ever used, the basic principle of gently handling tissue, as taught by Halsted and others, undoubtedly minimizes many of the harmful systemic effects of injury. The patient under general anesthesia may not react overtly at the time, but clinical experience has shown that rough surgery is much more likely to lead to a rough convalescence. This may, in fact, be due to the increased sensory stimulation thus evoked, but is probably due just as much or more to the increased tissue damage inflicted.

The extent of tissue damage is not only significant in relation to blood loss and the liability of infection but also in altering cell permeability in the entire wound area, especially when it is extensive and involves much muscle tissue. A great deal is being learned of this mechanism, particularly as it applies to the sodium, calcium, potassium, and perhaps magnesium ions. Interchanges between the former two, which are extracellular, and the latter two, which are intracellular, may prove of great clinical importance, especially in terms of replacement therapy with properly balanced electrolyte solutions. Suggestive of such changes in cell permeability are the investigations of Howard and associates (16) during the Korean War, showing that extensive injury is often followed by a fall in plasma sodium and sometimes by an increase in plasma potassium. Another factor in the wound capable of producing such systemic effects as fever and other "toxic" symptoms, is the release of toxic substances from the breakdown of large amounts of hemoglobin.

THE OUTLYING EFFECTS

In this section are discussed the systemic nonspecific effects of trauma not directly involving, but greatly influencing, the central nervous system, the liver, kidneys, and gastrointestinal tract. Respiratory and cardiac changes are even more important than those in other systems, but are discussed elsewhere.

These remote consequences of injury may be due to circulatory changes, to reflex nerve mechanisms, to the effects of increased adrenocortical steroids, or to other mechanisms. In any case, the changes may be so severe as to lead to actual tissue damage and even to death. Knowledge of these reactions therefore must be possessed by all physicians or surgeons dealing with the injured patients. Indeed, many of these outlying effects are shared by nonsurgical diseases in which severe stress is involved.

1. The injured patient exhibits perhaps the most obvious changes in the *central nervous system* function when he becomes depressed or loses consciousness or goes into coma. Hyperactivity as shown by apprehension, restlessness, or even delirium and convul-

crease in salivary secretion was also observed. Most striking was an experiment in which there was almost complete inhibition of salivary secretion in a blood donor after the bleeding of 500 ml. A controlled flow of 5 ml. per minute fell to less than 1 ml. almost immediately and returned only gradually to normal five hours afterward. A time factor probably explains the conflicting observations of increased uropepsin excretion after trauma and after ACTH stimulation (50). This probably also explains the observation that perforative peptic ulcer may occur during the postoperative period, presumably as a stress phenomenon (51). In the early days of cortisone therapy, it was found that, when used in patients with peptic ulcer, perforation often followed. It is now well known that the peak of adrenocortical stimulation by operation is not reached before eight hours (38). Thus the findings of achlorhydria by Howard may have been due to an immediate epinephrine response rather than to the effects of increased adrenocortical activity. It should be recalled that inhibition of gastric function was observed by Cannon in his early studies on fear, rage, and pain, and is, of course, a common clinical observation after various types of stress. A study was made of gallbladder function in the Korean conflict (52). Ten injured soldiers were studied by means of cholecystography and a temporary nonvisualization was established. This certainly must be added to the list of the nonspecific effects of trauma as one of the outlying manifestations in systems far removed from the wound.

OTHER CHANGES AFTER INJURY

Among the many observations made during injury, several have not been mentioned and are here presented. A fall in serum iron has been noted after operation (53), as well as a drop in the level of plasma amino acids (54, 55) associated with a fall in blood lipids. Similar falls in blood amino acid levels have been noted following infusion of ACTH.

The oliguria, the salt retention, and the potassium loss after operation and by the administration of adrenocortical steroids have already been noted. Calcium is also lost after trauma, especially following fractures, but this may be due more to the *atrophy of disuse* than to a systemic effect of injury itself. Atrophy always plays a potential part in any operation, injury, or even medical disease that is bed-confining. Moreover, muscle as well as bone is affected and accounts for much of the protein wastage following disease, entirely apart from that due to gluconeogenesis. The effects of such disuse atrophy have been studied in detail (56).

The vitamins are probably involved in the systemic effects of injury, but most is known of vitamin C, which disappears rapidly from the blood after injury despite a large intake (57). Since it does not appear in the urine, it is presumed to be destroyed or to have escaped in the damaged tissue. Of interest is the high vitamin C content of the adrenal cortex which, in animals, disappears after stress but does not if the hypophysis is first removed.

The effect of injury on carbohydrate metabolism is well known (58). Gluconeogenesis is probably under adrenocortical control. Hyperglycemia, glycosuria, and ketonuria have all been observed after trauma, but the latter is probably due almost entirely to starvation. A definite impairment in carbohydrate utilization has long been referred to as "traumatic diabetes," first studied in detail by Thomsen (58) in 1938, and later by Taylor and his associates (59).

A trypsin inhibitor in the urine was found by Dillard (60) to increase sixtyfold following a partial gastrectomy, returning to normal by the fifth day; to a fifteen-fold increase following a jejunostomy. The complicated changes in blood coagulation after operation are too confusing to discuss here, but the latest observations deal with an increase in a trypsinlike protease called plasmin (61), which is somehow related to the fibrinolytic ferment that produces liquefaction of cadaver blood and perhaps to unusual postoperative bleeding.

Post-traumatic Blood Changes. A fall in hemoglobin as well as in plasma protein concentration following operation and injury has often been noted and usually attributed to losses in the damaged tissues by actual bleeding or by inflammation (extravasation). Undoubtedly, much of it is to be explained in this way. Mention should be made, however, of another mechanism which may be at least partially responsible for the anemia following

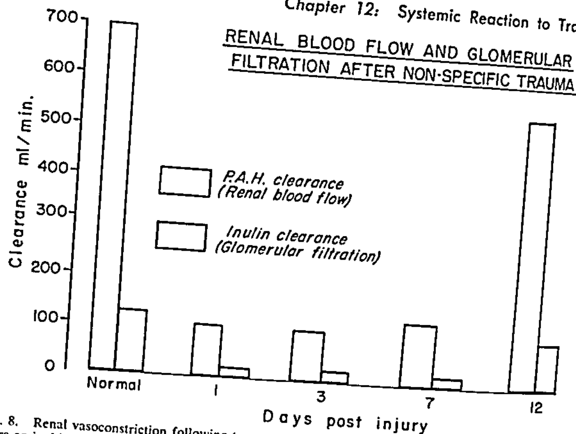


Fig. 8. Renal vasoconstriction following trauma. As a result of renal vasoconstriction, the clearances of para-aminohippurate and inulin, measuring renal blood flow and glomerular filtration respectively, decrease sharply after severe trauma. This response may persist for several days after restoration of a normal blood volume. This decreased renal function, at a time when the nitrogen load for excretion is maximal, may result in an elevated blood urea nitrogren concentration during the postoperative or post-injury period.

paired (46), the concentration increasing.

3. *Renal impairment* is so frequent after injury that it must perhaps be considered the most serious of the outlying effects of trauma. The causes are many. Post-transfusion reactions are well known. Shock and hypotension, by reducing renal blood flow, are often important factors (Fig. 8). After the central nervous system, renal tissue is perhaps the most sensitive to impairment or failure of blood flow. The time interval is not known exactly, but it is probable that a few hours, certainly less than four hours of complete renal ischemia, will lead to irreversible renal failure. Loss of renal blood flow for such a period may coexist with adequate cerebral blood flow due to selective vasoconstriction, by which a reduced amount of blood may be used to service the kidney at the expense of other tissues. Presumably, regional renal vasoconstriction may also occur, in the absence of blood loss, through reflex arcs initiated by severe pain. The practical significance of vasoconstriction is suggested by observations (48) in which such vasodilating and pain-relieving drugs as papaverine seemed to be followed by improved renal function. Other studies indicate that the autonomic blocking agents do not reverse the vasoconstriction in the renal circulation, suggesting that this response is not mediated by the epinephrine-sympathetic nervous mechanism. This may prove, biologically, to represent a separate response mechanism. The details of therapy in postoperative and post-traumatic renal impairment are discussed elsewhere.

4. The *gastrointestinal tract* is obviously affected by trauma far removed from the abdomen, as shown by the frequency with which the injured, and especially fracture patients, suffer nausea, vomiting, and occasionally paralytic ileus. Specific studies of gastrointestinal function carried out during the Korean War have thrown much light on this phenomenon. For example, it was found by Howard (49) that 10 injured soldiers studied 18 hours after injury showed evidence of decreased gastric secretion and motility. A de-

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trauma. The evidence, much of it originally based on both clinical and experimental observations, has been assembled by a young Swedish surgeon, Lars-Erik Gelin (62). Most of the clinical data consist of observations on fracture cases in which, of course, injury is not complicated by anesthesia or by operation. The concentration of hemoglobin in grams in 32 femoral-shaft fractures fell from 8.3 gm. per cent ± 2.3 gm. per cent to 6.2 gm. per cent ± 2.3 gm. by the tenth posttraumatic day, returning gradually to normal. The red cell count paralleled the hemoglobin concentration and the red cell sedimentation rate was in reverse, giving indeed a mirror image of the hemoglobin changes. The color index was unchanged. From a variety of clinical and convincing experimental evidence, this anemia was shown to be largely hemolytic and associated with erythrostasis, a term used to describe the increased viscosity and sludging of the blood, so graphically described in this country a few years ago by Knisely (63). Of considerable theoretical interest was the observation by Galin that low molecular dextran exerted a beneficial effect in decreasing sludging and anemia in contrast to high molecular dextran, which had the opposite influence. These provocative studies should be pursued.

In this country, Cockrell and Naumann (64) have found true hemoglobinemia (not due to artifact) after many operations and injuries and in certain systemic diseases, presumably as a manifestation of hemolysis. Postoperative increases of bilirubin have been frequent, although in most instances they have been explained by changes in hepatic function as well as by the breakdown of extrasavated red blood cells. It is possible, however, that many of these changes may be due to the mechanism described by Galin.

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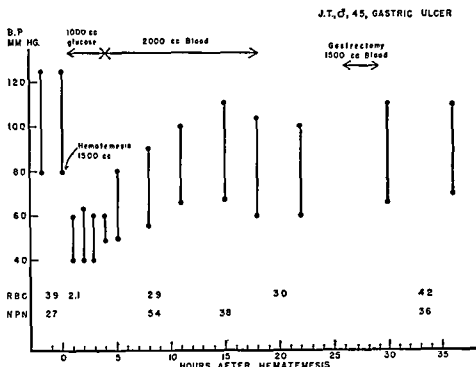


Fig. 1. Shock due to massive gastrointestinal hemorrhage. The patient, in excellent general condition, was admitted for the treatment of a known gastric ulcer. Shortly after admission, he suddenly vomited 1,500 ml. of almost pure blood and later had a tarry stool. Because 1,500 ml. of blood failed to restore his red cell count and because he showed other signs of continuing hemorrhage, he was operated on 24 hours later and an actively bleeding gastric ulcer was found and removed as part of a gastric resection. The postoperative course was uneventful.

Note the prompt fall in the red cell count, showing that hemodilution can occur within 30 minutes of a hemorrhage. Note also the failure of glucose to restore hypotension while blood transfusion was being prepared. It would have been better to give saline, still better to use Dextran. Note also the azotemia (rise of NPN) due undoubtedly to the absorption of digested blood which must have passed in large amounts into the small intestine.

This case is an example of the need for both adequate blood replacement and operation to stop the source of blood loss. (From Elman, R. Surgical Care, Appleton-Century-Crofts.)

From the historic point of view, the terms *primary* shock and *secondary* shock have sometimes been used, but actually they are more a source of confusion than clarification. The first usually refers to shock which occurs immediately after injury, but is transient and rapidly disappears; the second usually refers to shock which appears after an hour or two and is based upon definite and continuing disease, injury, or loss of blood. If these terms were used, secondary shock would really represent in general the type of shock herein considered.

CLINICAL CAUSES OF SHOCK

Of the many clinical recognizable disturbances which may produce shock, it is possible to classify them tentatively into three general categories, as listed below, although in a particular case there may be considerable overlapping. A fourth group is added because of the apparently growing frequency and recognition of adrenocortical insufficiency.

1. **Severe Loss of Extracellular Fluid.** The blood bed is, of course, the most important extracellular fluid compartment; therefore, loss of blood or *hemorrhage* is the most common and serious clinical disturbance which may lead to peripheral circulatory impairment (Fig. 1). The amount of blood lost without other factors that may produce shock varies with the age and sex of the individual and the rate of loss. Ordinarily, shock will follow a single, sudden loss of blood equal to 2 or 3 per cent of the body weight which, in a normal lean adult, is about 1.5 to 2.5 liters.

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SHOCK AND HEMORRHAGE

Shock and hemorrhage have, by tradition, been discussed together largely because they were supposed to represent similar but different clinical entities, each of which could be differentiated diagnostically. While it is true that hemorrhage alone, without complicating causes, produces more definite and more easily explained and recognized disturbances, it shares with shock the propensity for leading to *peripheral circulatory impairment*, which may be defined as a diminution in the rate of peripheral blood flow. This reduction in the supply of blood to peripheral tissues is the common denominator in all cases of shock, regardless of the contributing or precipitating factors and clinical effects produced. The modern concept is to consider shock as a general term and hemorrhage as one of its most common causes; but there are many other causes, some readily detectable, others difficult to determine and to understand. In many cases, shock is due to more than one cause. Finally, shock itself may produce such secondary manifestations as cerebral anoxia or renal impairment, which may be severe enough to threaten life. To illustrate its complexity, one needs only to realize that shock may follow severe trauma with or without hemorrhage, extensive burns, intestinal strangulation, adrenal insufficiency, cardiac failure, severe cerebral injury, tranfusion reaction, anaphylaxis, insulin-produced hypoglycemia, electrolyte disturbances, and fulminating infections. The term *surgical shock* is usually applied to shock that follows trauma or operation, or to shock which may require operation for its correction. This limitation, however, is often arbitrary. For example, myocardial infarction or a sudden hemorrhage from peptic ulcer may lead to shock. Neither is due to trauma; but the former is of medical, the latter of both medical and surgical interest.

Definition. Although the reader will find a variety of definitions of shock by different authorities (1, 2), its common characteristic, as mentioned above, is peripheral circulatory impairment or failure. Shock may be defined, therefore, as "a clinical state in which there is significant reduction in the peripheral circulation or rate of peripheral blood flow." This definition indicates that there are varying degrees of shock, a fact which is, indeed, in accord with clinical experience. The term is also used, really misused, in other conditions, called "nervous shock," which may occur after hearing tragic news, seeing anything intensely disagreeable or frightening, or experiencing profound fear and excruciating pain. Although sensorial depression may be so profound as to be followed by unconsciousness, as in fainting or syncope, the circulation is usually only temporarily impaired and recovery is prompt. Sometimes confused with shock are conditions producing collapse or prostration in which the circulation is not impaired at all. These are discussed in detail in Chapter 19.

In the following discussion, the subject of surgical shock will be approached from the clinical point of view by describing: (*a*) the various clinical causes, (*b*) the many contributing factors, (*c*) the clinical manifestations, (*d*) the pathogenesis, and (*e*) the treatment. An additional section will be devoted to a discussion of the "crush syndrome."

precipitates shock without other factors. More often these disturbances act as contributing causes, as listed below. Nevertheless, they all greatly influence the degree of shock, as noted especially during observations of the wounded during World War II. In these disturbances, as in the "toxic" effects mentioned above, vasomotor paralysis is probably the important factor in causing shock.

4. **Adrenal Insufficiency.** The occurrence of shock in patients with Addison's disease is, of course, an old observation. In view of recent and increasing use of cortisone, which may lead to adrenocortical atrophy, more patients may be expected to show shock whenever the drug is withdrawn suddenly. Bilateral adrenalectomy is also being carried out increasingly for various diseases, and thus has increased the likelihood of shock due to this cause. Postoperative and post-traumatic shock not explainable by any other clinical cause, as already mentioned, may also be due to transient adrenocortical insufficiency or exhaustion. The mechanism is obscure but may be due to increased capillary permeability and loss of plasma or to an increase in the blood bed because of vasomotor paralysis, as mentioned above.

CONTRIBUTING CLINICAL FACTORS IN SHOCK

The following list of other clinical factors in shock have long been known. Not only do they increase the likelihood and the severity of shock, but they may be able to initiate it themselves in isolated instances. The dividing line between these factors and those listed above is sometimes narrow or they may develop, but recognition of them separately is important, particularly since they play such an important part in therapy, as discussed later.

1. *Exposure to cold* may be a primary cause of shock when it is extreme enough to lower the body temperature below 28° C. (82° F.), the effect of which is now fairly well known due to extensive experience with induced hypothermia. Ordinarily, however, the mere exposure to cold aggravates shock or causes it to appear after relatively mild trauma or moderate hemorrhage. The presence of wet clothing adds to the seriousness of exposure to cold.

2. *Severe pain,* when excruciating, is said to be able to initiate shock, which is usually temporary even when the patient faints. When accompanied by hemorrhage, burn, or severe trauma, any degree of pain increases the liability of shock and aggravates its severity, probably by increasing vasoconstriction through sympathetic stimulation. This, when excessive, as discussed below, may increase the severity of shock by leading to a vicious cycle.

3. *Duration* of shock without treatment unquestionably aggravates its severity and makes the prognosis more grave. Any patient left in a condition of severe shock for as long as 12 to 24 hours can seldom be saved because the shock becomes irreversible and no form of treatment is effective.

4. *Anoxia* from any cause not only may precipitate circulatory failure but always contributes to its severity. Anoxia usually follows any type of respiratory impairment, including postoperative pulmonary complications, many of which are due to improper anesthesia. Since anoxia is actually produced by impaired blood flow and aggravated by excessive vasoconstriction, which increases capillary permeability and causes a further loss of fluids, a vicious circle may thus be set up.

5. *General anesthesia* always produces an added risk when administered to a patient in shock by increasing its severity. The depressing influence of ether on the blood pressure in shock has been demonstrated experimentally. Although nitrous oxide does not have this influence, it may be harmful for other reasons, particularly when given with a low percentage of oxygen. Any anesthetic leading to anoxia is, of course, distinctly to be avoided. The safest anesthetic for the shock patient is some form of regional or block anesthesia, provided it will meet the requirements.

6. *General factors* may play an important part as contributing to the severity of shock. Females are able to stand much greater losses of blood than males. Even in shock without hemorrhage, females are probably more resistant. Advanced age, the presence of other diseases—especially malnutrition, hypopro-

As to the speed of blood loss, time for compensatory restoration of plasma volume is important. Thus small intermittent hemorrhages are better tolerated than single large ones. However, a single large hemorrhage may seem well tolerated, but actually may lead to *a condition in which shock and even death* may follow a subsequent but small hemorrhage.

A large and rapid loss of extracellular fluid alone (other than blood) may lead to shock. This is undoubtedly an important cause of shock in severe burns, especially those in which hot water or oil or a flash comes in contact with a large area of the skin, producing *extensive edema and/or a large, discharging* wound. Some plasma is also lost and some red cells are destroyed, so that blood loss plays an important part. In extensive thrombophlebitis of sudden development, especially after operation, with or without loss of blood, or in the rapidly forming edema of an entire extremity due to a severe insect or snake bite, or in the crush syndrome, shock *may also occur for the same reason.* The volume of fluid lost into even one lower extremity may approach 4 or 5 liters. Loss of gastrointestinal secretions alone—if profuse and rapid enough, as in severe cholera—may also lead to shock. This loss may be to the outside through vomiting, diarrhea, or fistula, *or may be retained in dilated obstructed loops* of intestine. These conditions have, in common with hemorrhage, the inevitable fall in blood volume which undoubtedly is the reason for the peripheral circulatory impairment or failure.

2. **Severe Tissue Damage.** Without other factors, tissue damage may of itself produce shock (Fig. 2) entirely apart from the loss of extracellular fluid and blood into the damaged *area, even though the latter* is usually present and plays a decisive part. The mechanism is not always clear, but in some cases may have something to do with altered cell permeability, permitting the entrance of sodium and the escape of potassium from the intracellular space. In many instances, the existence of bacterial growth seems to be important by yielding products which impair the *peripheral circulation. This is certainly* true of strangulation of the intestine and in fulminating infections, often called "septic shock." Invasion by bacteria into normal tissue, producing similar toxic products, may also occur as a result of shock itself, thus leading to a vicious cycle aggravating the peripheral circulatory *impairment. The part played by the* rapid breakdown of extravasated red cells through the production of such toxic substances of catabolized hemoglobin as ferritin may also be significant. The mechanism in this group of clinical causes of shock may be due to the action of "toxic" and/or neurogenic factors leading to a decrease of peripheral blood flow through an increase in the blood bed, as discussed below.

3. **Nerve Disturbances.** Brain damage itself is sometimes associated with shock. Severe pain alone or intense emotion seldom



Fig. 2. Typical fall of arterial blood pressure after crushing muscles of the thigh in an experimental animal. (From Cannon, W. B. Traumatic Shock, D. Appleton-Century.)

tailed information should be recorded and, when summarized later, will be of tremendous value, not only in increasing our knowledge of shock but also in evaluating various methods of treatment (3).

Many confusing clinical manifestations of shock may also be clarified by referring to the definition of shock mentioned above and searching for the consequences of the impairment in the peripheral circulation. Perhaps a better description would be "impaired blood flow" or "a decrease in the amount of blood supplied to a given tissue." Important in this connection is the ability of the body to vary the blood supply to individual systems or organs. This occurs by a process known as *selective vasoconstriction*. Thus the extremities, which tolerate loss of blood rather well, may be deprived of much of their normal blood flow in order to conserve the remaining blood volume for more essential tissue such as the brain and the kidney. This vasoconstriction will be evident clinically in the form of cold, bloodless extremities. When the vasoconstriction affects the renal arteries, temporary renal impairment may occur, which indeed may be so severe as to lead of itself to further difficulty in terms of renal insufficiency. If severe, the hepatic circulation may be impaired, evidence of which has been obtained clinically, after hemorrhage in terms of hepatic function tests, and experimentally (4), by finding an increased blood ammonia level in hemorrhagic shock. Finally, vasoconstriction of the vessels supplying the brain may produce sufficient anoxia to lead to sensorial changes which, of course, is a serious manifestation of shock even in the absence of brain damage, because the nervous tissue is particularly sensitive to slight degrees of circulatory impairment or reduced blood flow.

1. The *general appearance* of the patient in severe shock frequently indicates its seriousness; the features are pinched, eyes sunken, pupils dilated, the lips pale or ashen in color, the forehead covered with beads of perspiration—in short, a picture often spoken of as the Hippocratic facies. The skin is cold and clammy over the entire body, but especially in the extremities and the face. Pallor, coldness, and perspiration are actually due to intense sympathetic stimulation which produces vasoconstriction for reasons already mentioned. While the reduced peripheral blood flow is obvious on inspection, measurement thereof is possible in terms of *capillary refilling time*. This can be done over the skin anywhere by noting the time required to refill a bloodless area produced by pressure of the examiner's finger. A better method is to render the nail bed bloodless by pressure on the fingernail and noting, on release, the number of seconds needed to refill. In the normal, it is less than a second. In severe shock, it may be several seconds.

The skin in severe shock shows a characteristic mottled appearance due to local pooling of venous blood alternating with bloodless areas. This, too, is obviously due to a diminution or even cessation of blood flow through the skin.

2. The *sensorium* may be unaffected, but is usually somewhat obtunded. When shock is severe or critical, the patient may appear unconscious so that if one raises his arm it falls to the bed at once as if lifeless. However, the patient will usually answer questions and complain of coldness, weakness, often of dizziness, exhaustion, sometimes of "deadness" of the extremities. Painful stimuli may evoke a groan or slight defensive movements. In the milder cases, the patient will appear listless and apathetic and show extreme asthenia. In certain patients, on the other hand, the sensorium may be so clear that nurses and interns may not suspect the presence of shock without careful examination. After severe hemorrhage, if sudden, syncope often follows; otherwise restlessness is apt to be a prominent manifestation which, indeed, is often of diagnostic value. Hyperactivity also occurs, but is usually due to such associated disturbances as severe emotion, and, in some cases, to infection and uremia.

3. The *peripheral circulatory impairment* is usually evident on inspection of the skin. The changes, as already described, are due not only to the decreased peripheral blood flow but also to the associated vasoconstriction. The reduced blood flow is also evident by the collapsed condition of the veins. The pulse is often rapid, at a rate of 120 to 140 per minute, of poor quality, soft, compressible, and sometimes thready in character. The pulse may even be impalpable at the

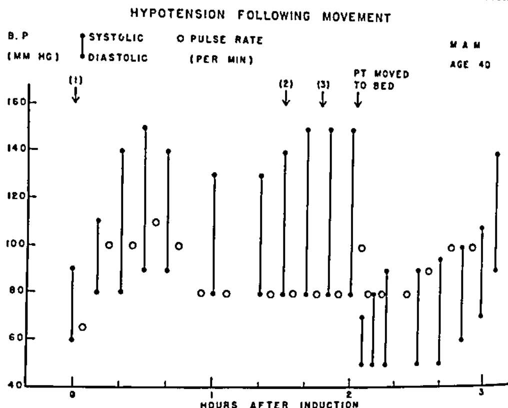


Fig. 3. Hypotension following movement under the anesthetic. While there was a transient fall of blood pressure with the induction of anesthesia at (1), the blood pressure was maintained throughout the operation for repair of a ventral hernia, at closure (2), and at the termination of anesthesia (3). Note the precipitous fall in blood pressure after the patient was moved from the operating table to her bed. There were no other signs of shock. Note that the pulse rate remained unchanged. No treatment was given and the pressure returned to normal within an hour. Although this type of hypotension is usually of little clinical significance and in this case did not jeopardize an uneventful convalescence, it should be avoided by more care in moving patients.

A more severe, prolonged, and dangerous fall in blood pressure usually follows a change from the supine to the so-called "jackknife" position during an abdominoperineal resection of the rectum. Few surgeons now use this change of position but perform the perineal part of the operation either by turning the patient on his side or by merely elevating and spreading the patient's legs while still supine. (From Elman, R. Surgical Care, Appleton-Century-Crofts.)

teinemia, and anemia—generally lowered vitality, and other factors have an obvious bearing on the likelihood and severity of shock.

During operation, numerous factors besides blood loss may lead to shock. One of the most serious, but fortunately not the most common, is coronary occlusion. Any one of numerous anesthetic complications including too much anesthetic, hypoxia, and hypercarbia may be the primary factor. Pronounced change in position may occasionally lead to a sudden unexplained fall in blood pressure (Fig. 3).

THE CLINICAL MANIFESTATIONS OF SHOCK

In a typically severe case of shock, the clinical manifestations, as listed below, are fairly easy to describe. In any given case, however, there are a number of factors which may lead to confusion. Many of these confusing factors are due to variations in the clinical causes of shock or, more often, to the rapid changes which may occur from hour to hour or even from minute to minute. These changes apply to all of the clinical manifestations, including especially blood pressure and pulse rate, upon which great reliance is placed too often, especially after a single observation. Surgical shock is really a *dynamic disturbance* due to rapidly changing stimuli and evoking rapid changes in response. For this reason alone, it is nearly always important for one individual to remain with the patient for the sole purpose of observing and recording the changes in the various clinical signs, particularly as influenced by therapy. Such de-

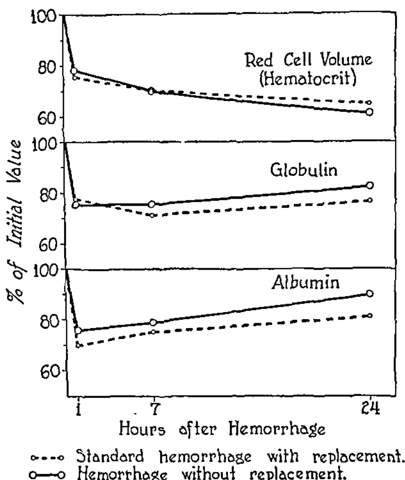


Fig. 5. Blood changes following experimental hemorrhage. A severe hemorrhage (3.5 per cent of body weight) was produced in dogs under local anesthesia and the changes measured in red cells, plasma albumin and globulin. Note the prompt drop at one hour in all three values, indicative of hemodilution with a cell-free protein-poor (i e., interstitial) fluid. Note also the continued fall in red cell volume at 7 and 24 hours, indicating further hemodilution but at a slower rate. Note also that the diluting fluid after the first hour must have contained some protein as shown by the slight increase in the concentration of both globulin and albumin, insufficient, however, to restore the value to normal by 24 hours. The two groups of curves (with and without replacement) refer to the injection of the same volume of isotonic saline to replace the blood removed; whether this was done or not seemed to have only a slight difference in the general pattern of the changes. (From Elman, Lischer & Davey. Am. J. Physio.)

Insufficient data are available to know whether hemodilution after hemorrhage in the human is as prompt and pronounced as it is in the dog The authors have seen a patient hospitalized for treatment of chronic duodenal ulcer with a normal red cell count, show a fall to 2.5 million per cm. within 30 minutes after a severe hematemesis. On the other hand, many patients with known severe bleeding may not exhibit hemodilution for several hours. Hemodilution is probably influenced by many factors, one of which is the giving of the barbiturate drugs which inhibit or prevent hemodilution (in the dog at least) after severe hemorrhage. The important practical application is that one cannot exclude hemorrhage in an acute case just because the red cell count is normal; however, in most cases it will drop eventually.

erally been observed. The value of blood volume measurement as a clinical guide is doubtful, because of difficulties in the technic of accurate measurement and in its interpretation. Blood chemical changes have been thoroughly studied and are similar to those reported for the severely injured. Many of the changes, such as acidosis, are due to a diminished clearance of the acid products of tissue metabolism either at their peripheral site of formation or by the kidneys. The decreased renal blood flow probably also explains the tendency toward an increased blood urea level, although other such factors as an in-

wrist but can be detected over the carotids. In a few cases, however, the pulse rate remains normal. Blood pressure may also remain unchanged for some time, or even may show a transitory rise. Sooner or later, hypotension is shown, although it may fluctuate from time to time. Thus, of all the clinical signs of impaired peripheral circulation in shock, a continuous record of variations in blood pressure probably gives the most accurate information, although single measurements may be misleading. Usually, the diastolic pressure begins to fall before the systolic does. Although the term *shock level* of blood pressure is used, it often is misleading because it varies greatly from one individual to another, dependent somewhat on the patient's normal pressure. For example, a fall in systolic pressure from 150 mm. to 70 mm. of mercury in one patient is much more likely to be accompanied by shock than a fall from 90 mm. to 60 mm. in another. The term *critical level* of blood pressure is also frequently misleading inasmuch as the blood pressure may become immeasurable in patients not actually suffering from shock at all. On the other hand, a patient after severe hemorrhage or trauma usually may show a systolic blood pressure of about 65 mm. of mercury, which might be called a critical level in the sense that any slight additional loss of blood or trauma will be followed by a disastrous decline in pressure. Other features of blood pressure are the rapidity with which the pressure falls and the duration of the lowered pressure. *A low venous pressure* is also present in shock and may be measured with a water manometer but can be readily estimated by noting the appearance and disappearance of the veins as the extremity is elevated or lowered.

4. The *body temperature* may be normal, although a fall of 1° to 2° C. is fairly common and is probably a reflection of the lowered blood flow and the reduced metabolic rate. The *respirations* may be unchanged but are usually shallow and rapid, except in severe hemorrhage when "air hunger" may be present. The latter is probably a compensatory mechanism to overcome the impaired gaseous metabolism resulting from the loss of oxygen carriers in the red cells.

5. *Laboratory examinations* may show a scanty, highly concentrated urine containing no abnormal elements, a normal, increased, or decreased red cell count depending upon the cause of shock (Figs. 4 and 5), and a *leucocytosis* (with eosinopenia due to the stress reaction as discussed in Chapter 12).

Blood volume changes have been extensively studied in shock and a fall has gen-

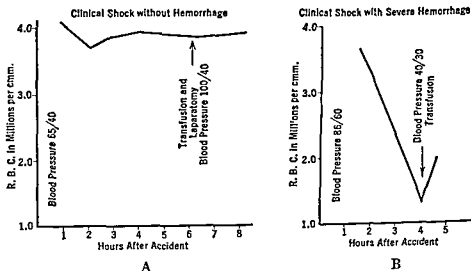


Fig 4. The red cell count (RBC) in shock. A, this patient was shot in several places, including the abdomen, but suffered very little loss of blood; he had all the clinical manifestations of shock. Note the absence of any fall in the erythrocyte count even though parenteral fluids were administered. B, this patient was struck by a street car, which crushed and severed both lower extremities; the loss of blood was considerable. Note the rapid fall in the erythrocyte count, indicating a dilution of the circulating blood. Parenteral fluids were given while the transfusion was being prepared.

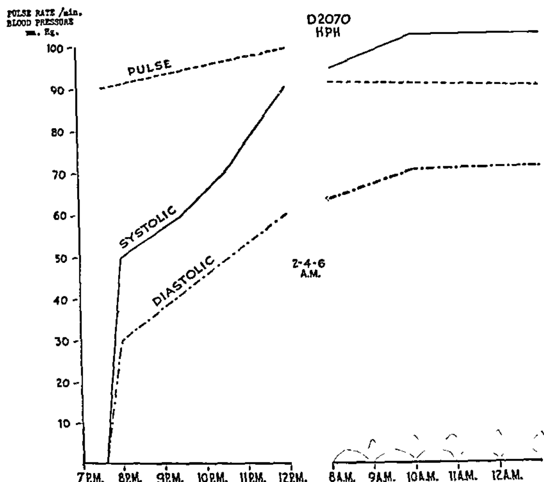


Fig. 6. Neurogenic shock. The patient, a 24-year-old female, was admitted almost at once following an altercation during which she was stabbed in the breast. On admission she was extremely frightened and apprehensive, looked pale, and her skin was cold and clammy. The blood pressure could not be measured but the pulse was slow (90 per minute). However, examination at the time, and subsequently, showed no evidence of loss of blood or serious injury. The laceration of the breast was small and superficial and did not require suture. One grain of codeine was injected, but no intravenous therapy was given. Note the prompt and spontaneous restoration of blood pressure. X-ray was negative and the red count 3.5 million, the white cell count 7,500. The patient was discharged the next day completely well. This might also be called a case of primary shock. (From Homer G. Phillips Hospital, St. Louis, Mo.)

2. The *size of the blood bed* cannot really be discussed without considering the size of the blood volume which fills it. Actually the two usually react in a reciprocal way—a rise or fall in one is accompanied by the same change in the other. Nevertheless, there are many conditions in which blood bed changes occur first, others in which the initial change is in blood volume. It is obvious, however, that with a constant blood volume any sudden increase in the size of the vascular bed, either by widening of the capillary area, including the opening of collapsed channels, or by dilatation of the arteries and veins, or by both, may lead to peripheral circulatory impairment or failure. Such a phenomenon is described as vasomotor paralysis and used to be a popular, but now discredited, theory of the pathogenesis of surgical shock. Nevertheless, there are certain kinds of shock which can be explained only by vasomotor paralysis. One example is the shock sometimes seen after spinal anesthesia, which does actually produce vasodilatation. An increase in the blood bed probably also occurs in the circulatory impairment in nerve disturbances. Another example is the shock in fulminating infections or in other conditions in which

creased breakdown of normal protein tissue, absorption of damaged protein tissue in wounds, and digestion of large amounts of blood in severe gastrointestinal hemorrhage are also responsible. Hyperglycemia is frequent and is due to a mechanism called "traumatic diabetes" or to pituitary adrenal stimulation, the so-called "alarm reaction."

Clinical Manifestations of Hemorrhage. A single severe hemorrhage, especially when it occurs without other complicating causes, usually produces an easily recognizable and characteristic clinical picture. The signs and symptoms, moreover, are often of diagnostic value, which is especially important in the absence of external evidence of loss of blood, as in a bleeding ectopic pregnancy. On the other hand, when hemorrhage is severe enough, particularly when it has lasted for some time or recurred, the peripheral circulatory impairment may become more pronounced and persistent, producing clinical manifestations which may be indistinguishable from those already described.

Extreme pallor, particularly evident in the blanched appearance of the lips and mucous membranes, is characteristic of severe hemorrhage, although cyanosis is occasionally superimposed. The patient may show little apathy but, rather, restlessness and some apprehension unless the hemorrhage is severe. Deep and rapid respirations are more likely, as in thirst, although the latter may be seen when the loss of fluid is not blood but rather interstitial fluid. Laboratory findings characteristic of severe loss of blood tend to be those of hemodilution. The red cell count falls, as does the hemoglobin concentration and the hematocrit, as well as the specific gravity of the whole blood, including the plasma protein concentration. These changes usually promptly follow severe loss of blood and are obviously due to passage of relatively protein-free interstitial fluid into the blood stream from the extracellular as well as intracellular space. The mechanism may be explained on the basis of Starling's hypothesis, which states that the colloidal osmotic pressure of the blood is balanced against the capillary pressure in maintaining the normal interchange between the blood and the interstitial tissue. Thus, severe hemorrhage, by inducing a fall in capillary pressure, leaves an unopposed colloidal osmotic pressure which acts to draw fluid into the blood bed. Indeed, hemodilution in severe hemorrhage may offer a striking contrast to hemoconcentration seen in other types of surgical shock and doubtless explains the greater pallor after bleeding. However, when circulatory impairment after an especially severe hemorrhage is severe and persistent, hemodilution as well as many of its manifestations may be partly or completely inhibited.

PATHOGENESIS OF SHOCK

Only the known clinical features have thus far been presented without definitely stating what their mechanisms are. What produces the profound impairment of the circulation is a question which can readily be answered in most cases (e.g., hemorrhage), but not in all. Answers may be found in the literature which have evoked endless discussion and have been responsible for a number of theories of shock. A toxic theory, an anemia theory, an acapnia theory, a neurogenic theory (Fig. 6), are but a few of those propounded. A complete and critical review of these theories has already been referred to (1). Here an attempt will be made to answer the above question with reference less to theories than to general physiologic mechanisms, particularly as they may be useful in outlining treatment.

Impairment of the Circulation. The circulation may be impaired by failure in one of the three main mechanisms which maintain it. These are 1. the force of the heart beat; 2. the size of the vascular bed; and 3. the blood volume, each of which will now be discussed.

1. The *heart* may fail as the result of myocardial infarction, and peripheral blood flow then falls, just as the flow does in a water system when the pump fails. However, this is not the case in surgical shock, in which cardiac function is normal. In cardiac failure the venous pressure is high; in shock, it is low. Respiratory changes are more likely and more pronounced in the circulatory impairment of cardiac disease. Nevertheless, the novice may mistake a coronary occlusion for surgical shock. This is decisive lest he make the disastrous mistake of giving intravenous fluids in the former which, of course, would greatly aggravate cardiac embarrassment.

due to a fall in blood volume due to increased capillary permeability.

The capillary wall represents the only real permeable link in the entire vascular chain. Thus, a change in permeability may lead to spontaneous alterations in blood volume. Increases in blood volume may occur by passage of fluid from the interstitial space into the blood stream, or decreases may occur by passage of fluid from the blood to the tissue spaces. Moreover, the capillaries themselves may dilate and contract, as do the arterioles and venules, thus also influencing the size of the blood bed. Much less is known of the behavior of capillaries than of the rest of the vascular tree. This may explain the fact that, in spite of the theoretical evidence just mentioned in favor of a general increase in capillary permeability during extreme vasoconstriction, few experimental studies have shown that this actually does occur (see below).

The role of vasomotor changes in shock is of more than theoretical significance. With their advent, the therapeutic application of long-acting vasoconstrictors and vasodilator drugs offers many opportunities not realized before. The selection of one or the other must be based on the need for combating excessive and undesirable vasodilation or vasoconstriction respectively.

Irreversible Shock. This term, widely used, is clinically important largely to emphasize the need for urgency in treatment. Death is inevitable in shock whenever the impairment or failure of blood flow has resulted in the death of vital tissues. Of all tissues, the central nervous system is, of course, the most sensitive to changes in blood flow; the cause of death in surgical shock may be said to follow severe impairment in the flow of blood through the brain. During surgical shock, as already mentioned, the body makes every effort to conserve what little blood there is for the central nervous system by selective and regional vasoconstriction. As long as this is possible, the patient is able to live. Next in importance to the ischemic changes in the brain are similar changes produced in the liver and the kidney. Even though the rest of the body tissues are less sensitive to a deficient blood flow, irreversible changes may occur when the circulation is impaired long enough for the capillary walls to become completely and permanently permeable. When this occurs, the circulation cannot be restored even with copious transfusions, for the capillary bed has lost its capacity for retaining within its lumen even normal whole blood injected in sufficient amounts to more than replace the blood lost. In such a case, the blood generally accumulates in the splanchnic area, where the capillaries are perhaps more vulnerable than in other areas. Irreversible shock, of course, may follow despite therapy because the lesion responsible for shock is not eradicated. This occurs in the presence of a persistently bleeding vessel which remains uncontrolled or when an extensively injured mass of tissue is the nidus for releasing "toxic" bacterial products or the site of continued loss of fluids. Anoxia, as already discussed, is an important factor, producing irreversibility. In still other cases, the factors which maintain excessive vasoconstriction are responsible for the fatal outcome.

These considerations emphasize the one feature of obvious therapeutic importance in shock, and that is the need for removing *all* the primary and contributing causes of shock as *early* as possible. Only if this is done, will restoration of the blood volume lead to a return of the circulation to normal and the maintenance of the blood pressure and blood flow at a safe level.

TREATMENT OF SURGICAL SHOCK

The therapy of surgical shock obviously depends on the nature of its clinical causes and their removal whenever possible. However, certain features of treatment may be applied to all cases regardless of etiology. It should be emphasized, however, that nonsurgical shock, particularly that due to heart failure, must clearly be excluded from most of the following therapeutic measures for reasons already mentioned. Not considered below is the use of cortisone in anaphylactic shock or in shock due to adrenal insufficiency. Septic shock, controllable in part by the use of properly chosen antibiotics, should also be mentioned as another type of therapy not discussed below.

1. Prevention of Shock. Prophylaxis applies largely to the trauma intentionally inflicted during operations. This includes care-

"toxic" absorption is supposed to occur. In the patient suffering peripheral circulatory impairment following spinal anesthesia, the clinical picture is, of course, not typically that of shock for the extremities are warm and dry in contrast to the cold, moist skin in surgical shock. Nevertheless, the fall of blood pressure in spinal anesthesia may be alarming and, indeed, may be fatal. In this and in other conditions where neurogenic or toxic factors are prominent, the fact that such vasoconstrictor drugs as levophed have proved valuable seems to indicate that an increase in the blood bed is the primary reason for shock. Moreover, it is important to know that vasomotor paralysis actually does occur in some cases, lest the common mistake be made of using such a drug for other hypotensive conditions in which the fall in blood pressure is due to loss of blood, and in which, indeed, there may be already excessive vasoconstriction.

In most cases of surgical shock, vasomotor paralysis is seldom present. Instead, definite and even excessive vasoconstriction is the rule. This important observation was made in 1909 by Seelig and Lyon (5) and has been confirmed by many observers since, as discussed at some length in the classic text of Cannon (6), years ago. It will be discussed in some detail after the next section.

3. The *blood volume* is of obvious importance in maintaining the integrity of the circulation. Reduction in blood volume is perhaps the most important mechanism in the pathogenesis of the circulatory impairment seen in most cases of surgical shock. Moreover, it is the easiest one to understand. In hemorrhage, for example, the immediate reduction in blood volume is obviously equal to the amount of the lost blood. In extensive crushing injuries much serum and blood may also escape by extravasation into the tissues, without obvious hemorrhage. It may, indeed, be great enough to produce circulatory impairment without resorting to theories of toxic absorption or vasomotor paralysis. The same applies to loss of extracellular (and intracellular) fluid into and from large burns and large areas of inflammatory edema, and even sometimes is seen in diarrhea if the process is rapid and extensive. These important observations have been made by many observers and have been well summarized by Blalock (7). Indeed, Blalock has also shown that even during abdominal operations there is a considerable exudation of plasma and other fluids, imperceptible perhaps, but which may actually be sufficient to lower blood volume and thus lead to shock.

In certain types of shock, notably shock due to anaphylaxis, to adrenal insufficiency, and to fulminating infection, the cause of the peripheral circulatory impairment or failure may be due either to an increase in the blood bed or to a reduction in blood volume, or perhaps to both. Vasomotor reactions in shock, as mentioned above, are so important that they will now be discussed separately.

VASOMOTOR REACTIONS IN SHOCK. Vasoconstriction, which affects arterioles and even capillaries, is undoubtedly a normal reaction to any sudden loss of blood or reduction in blood volume from other causes. This adjustment in the size of the blood bed downward in response to a reduced blood volume thus maintains blood pressure and blood flow. It does so, moreover, in a regional manner by selectively shunting what blood there is to more vital tissues at the expense of those less vulnerable. For example, vasoconstriction is usually intense in the vessels supplying the skin and the extremities, so that blood may be transferred from the periphery to the liver, kidneys, and especially to the central nervous system.

Excessive vasoconstriction, when it occurs, and we know that many compensatory mechanisms do "overshoot," may be of significance in the pathogenesis of surgical shock because, in itself, it may produce an additional spontaneous fall in blood volume. This mechanism is explained as follows: Extreme vasoconstriction inevitably reduces sharply the amount of blood entering the capillaries, thus interfering with normal interchange of fluid across the capillary wall. Indeed, Landis (8) showed years ago that local ischemia and asphyxia due to vasoconstriction increase capillary permeability and allow plasma to pass into the tissue spaces, a process which may be so diffuse as to produce no perceptible evidence of edema. An actual decrease in blood volume has been produced by Freeman (9) as a result of experimental vasoconstriction alone. Adrenal insufficiency may also be

Crush Syndrome, page 256). For this and other reasons, a tourniquet should be employed for the control of bleeding only if other available methods do not suffice and only for short intervals. If the temperature of the part distal to the constriction can be reduced by artificial means, deleterious metabolic changes from autolysis may be minimized. This is seldom possible. In mass casualties, the time of application of the tourniquet should be indicated lest too long a period elapse before definitive therapy, thus endangering the integrity of the limb.

The injection of so-called hemostatic agents to stop internal bleeding is to be condemned; there is no evidence of their value, at least at the time of this writing.

3. **Conservation of Body Heat.** This traditional and time-honored method of therapy is often used to the detriment of the patient inasmuch as the application of heat in shock may actually be deleterious, as shown by Blalock and Mason (10). A common mistake is the wrapping of the injured patient in warm, heavy blankets, even applying external heat, when the environment temperature is normal or high. Excessive application of heat produces cutaneous vasodilatation, which is harmful because it withdraws blood from vital tissues needing it urgently. Moreover, local heat increases tissue metabolism in the skin unnecessarily, producing harmful acidic catabolic products. Finally, in profoundly depressed patients there is always the hazard of producing a burn with hot-water bottles. Although the patient in shock complains of being cold, it is much safer and just as effective to wrap him in blankets, thus conserving his own body heat, than it is to apply external heat. This is particularly important when the patient has been exposed to cold which, as already mentioned, unnecessarily increases the already excessive peripheral vasoconstriction. It is also important that cold, wet clothing be removed at once and replaced with a warm covering or blankets, not only over but under the patient.

4. **Rest.** Immobilization of the injured part is obviously necessary. The horizontal position, preferably in bed, is also mandatory. Indeed, any movement of the body, as already mentioned above, may prove harmful. The position of the patient with his feet elevated and head lowered is so universally used that it is called the *shock position* (Fig. 8) and is readily achieved by placing blocks of wood

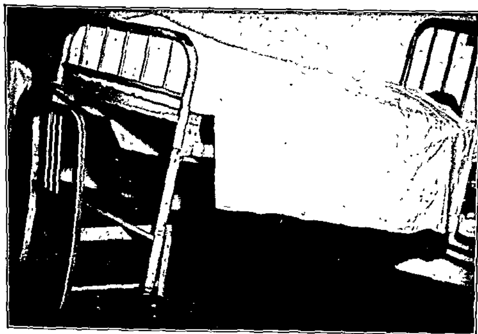


Fig. 8. Bed in the "shock position"; instead of shock blocks under the feet of the bed, a chair has been used.

ful preoperative preparation. It implies the gentle handling of tissues, complete hemostasis, replacing large blood losses as soon as or immediately after they occur, a minimum of exposure of viscera to the air, the control of the patient's apprehension and pain, careful anesthesia, and finally, proper postoperative care. These details are all described elsewhere. It is important here to emphasize the fact that, if these precautions are followed, seldom will the surgeon encounter postoperative shock.

Avoidance of delay in the treatment of injured patients in general will minimize greatly the incidence as well as the severity of shock. Even when shock is not present, undue delay in treatment may permit it to develop. When shock is already present, prompt therapy may halt its progress and promote its disappearance. Extremely important is the avoidance of unnecessary and rough movement of the patient as, for example, from bed to table or vice versa after operation or severe injury. Significant and sometimes alarming circulatory impairment will follow such movement.

2. **Control of Hemorrhage.** The removal of the cause of hemorrhage is obviously indicated in order to prevent further loss of blood. Often, however, when the patient is seen by the surgeon, bleeding has already stopped. The various methods of controlling hemorrhage are described in Chapter 14.

Cessation of bleeding is aided by several natural, spontaneous mechanisms. The drop in blood pressure itself frequently is sufficient to stop further blood loss even in moderate hemorrhage when the vessel is not too large. Such local factors as contraction of the severed vessel, the development of thrombokinase from torn tissue (especially in parenchymatous organs) to promote clotting, and the development of a hematoma which, by its pressure, compresses the bleeding point are also favorable in stopping further loss of blood. Finally, there is a mechanism which increases the clotting power of the blood as hemorrhage continues, due presumably to an increased production of fibrinogen which spontaneously decreases the clotting time, thus tending to stop the leak with a thrombus.

A tourniquet is probably one of the oldest methods of controlling hemorrhage from an extremity (Fig. 7). It is now known that severe systemic effects are, unfortunately, likely to follow the release of a tourniquet which has been left in place for several hours (see

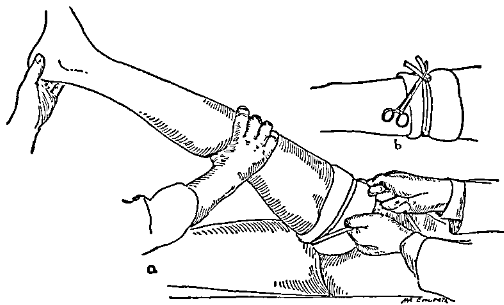


Fig. 7. The proper method of applying a tourniquet to the upper thigh in severe hemorrhage from the lower extremity. a, Application of the rubber tubing with sufficient force to obliterate the femoral artery. A counter force against the knee is exerted by an assistant. The limb is elevated during this procedure. b, Tourniquet in place with a clamp to insure against its becoming loose. Note the towel beneath the tourniquet to insure against injury to soft tissue. This is especially important in the arm where the nerves are less completely protected by overlying muscle and hence are injured more readily.

though saline solution is still the simplest and most effective, and is readily available for use in such cases, it is true, unfortunately, that the results, though beneficial, are usually temporary (14, 15). This is shown by the fact that the rise in blood pressure is transient, because the injected fluid does not remain in the blood stream but gradually filters out through the capillary wall into the tissue spaces. This may be due partly to the increased capillary permeability, as already mentioned, particularly when there has been gross capillary damage. Just as important, however, is the fact that saline and glucose solutions contain no colloids and only colloids are able to remain within the intact capillaries, the walls of which act as semipermeable membrane through which crystalloid can readily pass. Much of the normal function of the large protein molecule of the plasma is, indeed, due to its colloidal property, as originally described by Starling, and is the basis for his hypothesis, first recorded nearly 50 years ago but still known to be important in the treatment of shock.

Whole blood transfusions are widely and effectively used as the best method of restoring blood volume after hemorrhage. The increased availability of blood banks have made this advance possible. The amount of blood required is often large, depending, of course, upon the amount that has been lost. In the severely injured in which blood loss is continuing, many liters may be necessary during operations performed for the control of hemorrhage (16, 17). Usually at least 20 ml. per kilogram of body weight is needed as the initial dose. In the severely shocked patient, several veins may have to be used simultaneously. Even the intraarterial route may be indicated in special cases when the intravenous channel fails to restore the circulation.

When blood is not immediately available, or when some time is necessary to properly type and/or match the blood, blood substitutes may be necessary. In emergencies of this kind, the time factor may be so important that restoration of blood volume by any method may prevent irreversible shock. Solutions containing salt in such a case are better than those with glucose, since the latter is rapidly metabolized. For reasons already mentioned, however, a colloidal solution is even better. The most widely used at present is a substance, first devised and used in Sweden, called *dextran*. Such substances as acacia, periston, and pectin have the disadvantage of not being metabolized by the body, since they are really foreign bodies. Dextran, on the other hand, is a large molecule composed of glucose; gelatin is a protein molecule containing only amino acids; both are normally metabolized. For a single injection, dextran or gelatin solution may be advisable when blood is not available or is being prepared. These solutions, moreover, will be found to conserve blood in the vein because a few cases will respond so well that further infusion will be unnecessary. Dextran, as manufactured in this country, should, however, be used in amounts not exceeding 1 liter. Larger infusions have been observed to provoke capillary bleeding, a complication which has not been reported following large infusions of Swedish dextran.

Plasma is perhaps the best whole blood substitute and has the advantage over whole blood of greater convenience, because it can be stored longer and requires no typing. Pooled plasma, however, has an increased hazard of transmitting homologous serum hepatitis, the incidence of which is appreciable, especially in some parts of the country. However, storage of plasma at room temperature has been shown to reduce or eliminate this danger (Allen, 18). When plasma rather than blood has been lost, the former is preferable. Pure serum albumin is also available as a concentrated 25 per cent solution and is, perhaps, the best blood substitute of all.

Solutions of electrolytes are specifically indicated when the fall in blood volume is not due to loss of blood but to loss of extracellular and intracellular fluid. Various causes for the loss of extracellular fluid have already been discussed. Only when the loss is severe and rapid does shock follow, yet in such a case blood would not be effective and might, indeed, be harmful in instigating pulmonary edema. Replacement therapy would, in such cases, mean adequate infusion of salt solution or, better still, physiologic salt solution, often called "balanced Ringer's solution." Since in these cases some blood or plasma

(shock blocks) under the foot of the bed. The value of this position is probably due to the conservation by gravity of blood otherwise stagnant in the extremities, thus helping to overcome cerebral anoxia. It has, however, the disadvantage of impairing respiration by pressure of the abdominal contents on the diaphragm.

Posture is so important in shock that it has even been used in the diagnosis of the severity of occult hemorrhage. If a patient who has suffered internal gastrointestinal bleeding is allowed to sit up in bed, an increase in pulse rate or a fall in blood pressure is supposed to indicate a severe rather than a moderate hemorrhage.

5. **Relief of Pain.** Since pain is one of the contributing causes of shock, relief of pain is a sine qua non. The pain in fractures is best treated by immediate immobilization and traction. In the extremities, a Thomas splint is perhaps the best method and, indeed, during World War I these splints were applied in the field. It was noted that their use was a most important factor in reducing the incidence of traumatic shock (Cannon).

Drugs, especially morphine, should be used for the relief of pain only when pain is definitely present. Of interest are the observations of Beecher (11), who, in World War II, found that but 20 per cent of freshly wounded patients were actually in pain. For them, the barbiturates were usually sufficient to allay restlessness and to control apprehension. Such sedation prevents movement which might increase bleeding by discharging clots or by interfering with their formation. Morphine, though indicated for severe pain, should be withheld in any patient with a head injury or an intraabdominal lesion because of its tendency to mask symptoms and thus to interfere with diagnosis and treatment. Morphine, moreover, should not be given in the presence of pulmonary disease because of its depressive action on respiration.

6. **Increase of Blood Volume.** The important basic aim in the therapy of shock is to improve the peripheral circulation by increasing blood flow (12). This means, in most cases, a prompt and permanent increase in the blood volume unless, of course, such improvement is evident as a result of the methods already mentioned. In the presence of an inaccessible or immediately uncontrollable source of hemorrhage, however, the method used to increase blood volume, such as transfusion, may be ineffective or only temporarily effective because of continued or recurrent hemorrhage, for which an operation may be indicated. This problem is discussed below.

While the *blood volume* may increase spontaneously, especially after hemorrhage, by the passage of fluid from the interstitial spaces into the blood stream, this process, called hemodilution, necessarily leads to anemia and hypoproteinemia. If the bleeding stops, if the anemia is not too great, and if there is no further disease, this compensatory mechanism is adequate, for eventually the lost hemoglobin and plasma protein are regenerated from food without special therapy. Nevertheless, it is important, even in the acute phase, to maintain a good fluid and food intake. As early as World War I, and perhaps earlier, it was often noted that shock was much less likely to occur in soldiers having access to plenty of water than in those deprived of water, other things being the same. Oral administration of fluid is, therefore, extremely important in the treatment of shock except, of course, when contraindicated by the presence of intraabdominal disease. Under these conditions, the parenteral route must be used to prevent dehydration. More commonly, the parenteral, particularly the intravenous, channel is necessary for the restoration of blood volume critically low and not restored spontaneously. Indeed, in such cases the need for increasing the blood volume may be so urgent that speed becomes a sine qua non inasmuch as shock allowed to persist leads to irreversible changes.

The value of intravenous infusions in restoring blood volume, blood pressure, and blood flow in shock was noted long before the mechanism was understood. As early as 1820, dramatic and undoubtedly accurate observations were recorded showing the benefits following the infusion of saline solution in cholera. Even milk was injected, as well as glucose and sucrose (13). Later, simple solutions were employed instead of blood to replace blood loss after hemorrhage, largely as a matter of convenience and speed, or because of the difficulties and delay associated with the giving of a blood transfusion. Al-

through the capillary walls, leading to a fall in blood volume, activated by hemorrhage into the lacerated tissue.

This well-known initial mechanism is followed, however, by another pathologic change, due to serious renal damage apparently caused by toxins originating from the local area, which occurs a few days later. Blalock (20) has actually demonstrated that the thoracic duct lymph collected after removing animals from a press crushing a lower extremity was definitely toxic when administered to normal animals. Such animals develop hemoconcentration and casts and blood in the urine, and some die as a result of the injection. Bywaters attributed this renal damage to myohemoglobin liberated from the injured muscle, although he felt too that reflex renal arterial spasm was perhaps of greater significance. More recent studies have implicated some of the breakdown products of hemoglobin which apparently are toxic under certain conditions. Ferratin has been implicated (21) as one of the substances normally metabolized in the liver, but in conditions of shock persisting and leading to further circulatory impairment.

Clinical Manifestations. The victim of a crush syndrome while still under the debris may reveal no symptoms of impending shock; the initial pain may even have disappeared. Within a few hours after release of the crush, however, the involved extremity becomes extremely swollen. With this swelling the patient develops all of the signs of shock similar to that of surgical shock due to rapid loss of plasma or to severe hemorrhage. A variable amount of ecchymosis appears over the injured area, depending upon the amount of subcutaneous injury. Fractures or injuries to nerves and other tissues may also be present, and search should be made for them. These patients generally respond to shock therapy, although there is always the likelihood that the infused fluid will continue to enter the damaged limb, increasing swelling, and doing little good in respect to restoring the circulation. A few days later, the manifestations of renal damage appear. Blood, albumin, and casts are found in the urine, later oliguria and finally anuria with resultant uremia develop, commonly terminating in death.

Treatment. The prevention of edema and of serious renal complications demands first priority. It has been recommended that compression bandages be applied to the crushed extremities immediately after the victim is extricated in order to minimize swelling and the escape of infused fluid. The application of cold to the extremity would appear logical theoretically, but Duncan and Blalock (22) have observed that, in animal experiments, this therapy was not effective unless it was started with the onset of decompression. In any case, it is well known that such damaged extremities should be kept cool and not subjected to the harmful effects of heat. Since excessive vasoconstriction is often present, atropine hexamethonium and papaverine have been used. Sympathetic block by paravertebral injection of novocain may be still more effective. Cortisone may be tried. If the trauma is severe, amputation may be imperative.

Crush Syndrome in Other Injuries. A "toxic" factor in the production of shock is now generally recognized, instigated largely by these studies on the crush syndrome. Formerly a "toxic" theory of shock was used to explain all cases. In the case of crush injuries, evidence seems clear that there is such a factor, even though its exact nature is unknown. A similar factor, though of slower development, is probably present in so-called *tourniquet shock*, produced experimentally 30 years ago by Cannon and Bayliss, but studied in more detail in recent years (23). This condition, which may also be seen clinically when a tourniquet is left on for several hours, is associated with the loss of extracellular fluid, plasma, and blood into the extremities as soon as the tourniquet is removed. Although the manifestations of shock may be controlled by adequate replacement therapy, the relief is not complete, suggesting therefore that a "toxic" factor is superimposed upon the lost plasma. Repeated observations in the treatment of war casualties, confirmed by experience in the Korean conflict, have shown clearly that clinical shock developing under such circumstances often responds only slightly to transfusion and that the removal of irretrievably damaged muscle plays an essential part in the control not only of shock but also of renal impairment. Infection undoubtedly plays a part in the relief of

also may be lost, a small amount of plasma or blood should also be given.

The circulatory impairment due to a fall in blood volume may sometimes be improved by a reduction in the size of the *vascular bed.* This may be done by bandaging the extremities, although the clinical results are apt to be disappointing. Vasoconstrictor drugs also may reduce the total blood bed and formerly were used extensively in the treatment of shock. They are now known to be harmful since they increase an already existing, even excessive, vasoconstriction. On the other hand, when surgical shock is due largely to neurogenic, "toxic," or other factors and there has been no loss (or adequate correction of loss) of blood or other fluids, the long-acting vasoconstricting drugs such as levophed (levarterol bitartrate, l-norepinephrine) may have a distinct place in therapy. The dramatic effect of hydrocortisone in combating shock due to anaphylaxis and in adrenocortical failure is not entirely clear. It is likely that its action, however, is in the capillaries, reducing their permeability and thus conserving blood volume.

7. **Operations in Surgical Shock.** A needed operation is, in general, postponed in the presence of surgical shock until this condition is at least partially relieved, in order to avoid the greatly increased risk of adding the trauma of operation and of anesthesia to the effects of shock. Nevertheless, operation is sometimes necessary to prevent or control the actual cause of shock as, for example, the removal of gangrenous intestine. Failure to do so is fatal. A more common example is the need for operation to control internal hemorrhage which threatens life despite nonoperative measures. Such an operation, however, must offer some assurance that the bleeding can be controlled. This is usually possible in ruptured ectopic pregnancy, postoperative hemorrhage, gunshot or stab wounds of the abdomen, rupture of the spleen, and in certain cases of persistent gastrointestinal hemorrhage. The possibility of actually using some or all of the escaped blood by collecting it and reintroducing it into the circulation (refusion, autotransfusion) adds to the advantages of the operation. The risk may be minimized somewhat by choosing an anesthetic that will not increase anoxia. Transfusions should, of course, be started before and maintained throughout the operation. Delay in operation for internal bleeding is indicated when there is good evidence of a spontaneous cessation of the hemorrhage.

Operation for the removal of badly damaged and necrotic tissue is obviously urgent, but may await control of the initial shock following the injury. However, the role of necrotic muscle is so important in promoting shock that long delay in its excision is unjustified. This is especially true inasmuch as devitalized tissue may be a nidus for serious infection or may play an important part in initiating and maintaining renal impairment.

8. **Oxygen.** Insofar as anoxia occurs in shock, inhalation of oxygen would seem to be of some value. On the other hand, the arterial blood is usually saturated normally in surgical shock. Nevertheless, oxygen inhalations have proved beneficial, particularly when respiratory difficulties are present. The gas is given in high concentration (95 per cent with 5 per cent CO_2). Avoidance of carbon dioxide accumulation is, of course, also important.

CRUSH SYNDROME

The so-called crush syndrome has an interesting history and many implications in the therapy of shock, even at the present time, and is therefore considered under this separate heading. Crush injuries are seen commonly during wartime, not so much in military personnel, but among civilians after they have been extricated from beneath the debris of bombed buildings. Many such victims were seen and studied during the London blitz by Bywaters and others (19). Much of the information concerning the crush syndrome has application to tourniquet shock, which is described later, and extensive muscle damage from penetrating missiles of any kind.

Pathogenesis. The initial shock seen in these crushed individuals is readily explained by the fall in blood volume from the loss of extracellular fluid, blood, and plasma into the injured area. The crushing of the tissues produces obvious damage and anoxia, which increases capillary permeability. However, it is only after the victim is extricated that the circulation returns; the fluid then is lost

14

WOUNDS

Wounds may be inflicted accidentally or produced by the surgeon to correct a disease process. Those produced by the surgeon are comparatively simple, whereas those inflicted accidentally may be so extensive and damaging that they may kill the patient. Although industry is constantly adding safety factors to reduce incidence and severity of injury, the human being himself is showing very little ability to reduce injury for which he is primarily responsible. For example, in 1958 there were 91,000 accidental deaths and 9,100,000 disabling injuries in the U.S.; of this group, 37,000 of the deaths and 1,350,000 of the injuries were caused by automobiles. Not fully appreciated is the fact that 27,000 deaths and 4,000,000 injuries were sustained in the home (data from the National Safety Council). These appalling figures indicate clearly that the care of injuries consumes a huge proportion of the physician's time. Moreover, there is no indication that operations for other surgical lesions are decreasing proportionately. Accordingly, the care of wounds must remain a very important phase of the surgeon's training and life (1, 2).

KINDS OF INJURY

The local response of the body to injury depends largely on its kind and severity. In general the simplest injuries are those which damage cells without impairing their viability, such as a stroke on the skin with a dull blunt object, or a mild scald or sunburn. The more severe injuries cause actual death of cells, called necrosis, or, when the tissue involved is extensive, gangrene. On the other hand, tissue may be divided or separated with very little or no necrosis. Classified according to type, the various injurious agents may be described as follows.

1. *Mechanical* (or *traumatic agents*) are perhaps the most common and vary greatly in degree. Wounds inflicted by mechanical trauma may be of numerous types. They may be closed or open; in general, the former are designated as contusions and the latter as lacerations (Fig. 1).

2. *Chemical irritants* are often inadvertently used in salves and solutions; especially dangerous are those containing phenol which



Fig. 1. Traumatic injury. Two deep lacerations of the scalp sustained during an auto accident. Severed temporal muscle can be seen in the lower part of the posterior wound.

such "toxins," as shown by the beneficial effect of chemotherapy (24, 25).

A similar mechanism may occur in certain extensive burns in which moist, necrotic skin forms and, on disintegration, produces by autolysis certain products which, by absorption or otherwise, produce signs of toxemia. The same is true of strangulated intestine. In any case, there seems to be no question that there is indeed a "toxic" factor in any patient suffering from shock associated with extensive tissue and particularly muscle damage, even though there may also be a great loss of fluid, including blood or plasma, into the damaged area.

The practical application of these findings seem clear. One cannot treat shock by single methods of therapy. In many cases a combination of methods is necessary—as blood transfusion and operation for the control of bleeding, both of which may be necessary for the removal of necrotic tissue as well as for replacement therapy in the crush syndrome.

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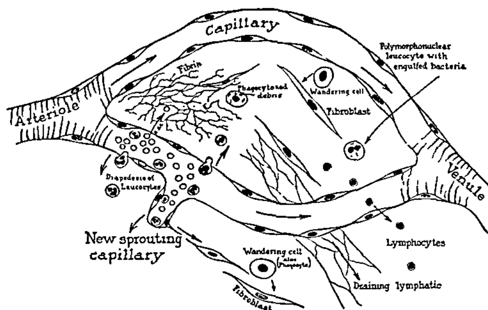


Fig. 5. Diagram illustrating the main histologic features of inflammation and repair.

energy, and stimulate the anterior pituitary to secrete ACTH (adrenocorticotrophic hormone) and STH (the somatotropic hormone). The adrenal cortex is activated by ACTH to secrete gluco-corticoids, such as cortisone, and by STH to secrete mineralo-corticoids, such as desoxycorticosterone. This stage in response may be classified as the *stage of resistance.*

As noted above the reactions involved in the alarm reaction observed in trauma are equivalent to the various responses induced by ACTH. These reactions are numerous (3); many appear to be detrimental to the body (4) and probably are. There is a retention of sodium chloride and water, but potassium and calcium are excreted in increased amounts. There is an appreciable negative nitrogen balance, a deleterious effect of trauma first emphasized by Cuthbertson (5) years ago. Utilization of carbohydrates is decreased by an anti-insulin effect. There is an increase in the urinary excretion of 11 oxysteroids and 17 ketosteroids. An eosinopenia is fairly constant.

The process of *wound healing* may be divided into three phases: 1. the initial or lag phase; 2. the phase of fibroplasia; and 3. the phase of scar contraction. One of the first local reactions to trauma is the deposition of an exudate (serum, blood, and lymph) which usually clots, except when accumulating in large quantities. The process of removal of dead tissue cells is necessary to wound healing and begins almost immediately after the injury. Phagocytic cells including leukocytes, histiocytes, and macrophages are brought to the wound by an increased blood supply (Fig. 5). These cells are aided by enzymes, mostly of the proteolytic type, which dissolve dead cells either inside or outside the phagocytic cells. By the second day there is a proliferation and migration of endothelial capillary buds into the blood clot. Proliferation of fibroblasts from the wound edges is profuse. The product of humoral and cellular response just described is called *granulation tissue* (Fig. 6); it is necessary to the healing of all wounds. The aging process of granulation tissue is dependent upon the fibroblasts. These cells secrete collagen (a protein) which produces strength in the adhesion between the wound edges. The old collagenous connective tissue at the edges of the wound fuses into the new collagenous tissue by contiguity of cell growth and development of collagen fibrils. The tensile strength of the wound is dependent primarily upon the collagen rather than on fibroplasia per se (6). The appearance of collagen fibrils (about the sixth day) in the granulation tissue represents the end stage of the lag period when tensile strength is lacking.



Fig. 2. Chemical injury. A spreading ulcer of the leg developed in this patient after a simple laceration was treated by repeated application of a salve containing phenol. Rapid healing followed cessation of the chemical irritation.

produces definite cell injury and in some cases actual death of tissue (Fig. 2). Ordinarily, the serious chemical injuries are due to accidental contacts with strong acids, alkalis, liquid bromine, and similar agents which destroy the tissue with which they come in contact. Insect and snake bites are often serious because of the introduction of toxic chemical substances which injure cells directly.

3. *Radiant energy* such as heat and also x-ray and radium have the power to incite an inflammatory reaction and, if severe, actually to kill tissue. Atomic energy has introduced a new combination of heat and radioactive injury. Electricity of high amperage not only can burn tissue but also may coagulate cytoplasm and thus kill cells immediately. By

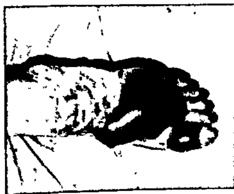


Fig. 3. Thermal injury. This blister has the same appearance as if caused by excessive heat. Actually it was produced by excessive exposure to severe cold; it represents an injury due to frostbite.



Fig. 4. Bacterial injury. Local necrosis caused by a staphylococcus infection (furuncle) which has already opened and discharged its content of pus.

chilling, cold can injure tissue (Fig. 3) and, by freezing, can actually kill it. The effects of these agents will be described in Chapter 16.

4. *Pathogenic bacteria* and their products of growth or disintegration are far and away the most important and most frequent agents capable of inciting the inflammatory reaction, acting not only as the primary agent, but more commonly entering the field after other agents have started the injury (Fig. 4). Bacteria, of course, not only damage cells but are capable of provoking extensive necrosis, and frequently invade the entire body and challenge life itself.

HEALING OF WOUNDS

A wound may be defined as a solution of the continuity of tissue due to mechanical force or related mechanisms. Under the latter factor, thermal, chemical, and bacterial agents are included. Wounds give rise to various reactions in the body which determine the site of healing, final outcome, and so forth.

Physiologic and Cellular Reactions. Most of the reactions to trauma are the result of hormonal response as elucidated by Selye and often spoken of as the *alarm reaction*, which develops almost universally when the trauma is severe. The local nerve endings send stimuli to the autonomic nervous system; these stimuli become amplified in the ganglia and pass through the sympathetic system to the medulla of the adrenal gland which secretes large amounts of epinephrine and norepinephrine. These agents raise the blood pressure, mobilize liver glycogen to provide glucose for

sile strength. However, scar tissue is usually not as resistant to tension as is normal tissue; in fact, when present to excess, it may lead to abnormal stretching and herniation. Contracture of the scar is an important phase of healing. In the first place, it reduces the size of the defect and thus aids the process of epithelization. The contracture is most noted in the longitudinal axis of the wound; it usually takes effect in areas of least resistance thus explaining to a great extent the marked deformity about the eyes, mouth, lips, and flexor surfaces of joints in burns or in other wounds in which massive tissue destruction is present. There is little elasticity in scar tissue. Although scar contracture often results in serious deformity, it does exert some favorable influence. For example, it reduces the size of defects and exerts a squeezing effect on the wound; this compressing effect obliterates the excess capillaries and squeezes out the edema fluid.

Epithelial growth starts almost immediately after injury but not until the dead tissue is removed; thus, epithelization develops earlier in clean wounds than in jagged wounds which have been incompletely debrided. When a defect is present, epithelium will not grow across the intervening clot until granulation tissue has developed and has filled the defect. The primary focus for skin regeneration is from the stratum germinativum.

A crust or scab develops over almost all superficial wounds. To a certain extent, it is part of nature's process of healing. The crust represents dried secretion from the wound and adheres closely to the wound. In this respect, it is protective, since it minimizes bacterial contamination; moreover, it adds to the tensile strength because it is tough and densely adherent. However, on occasions, the crust appears to cover the line of epithelial regrowth so densely that epithelial regeneration may be slowed down. To prevent this the crust may be soaked off. If it is lifted off forcibly, some of the newly regenerated skin may be torn off. When epithelization is complete, a crust will no longer develop.

Abnormal Physiologic Factors Affecting Healing of Wounds. In 1937, Lanman and Ingalls (8) demonstrated experimentally that when the vitamin C content of blood approximated the scorbutic level, delayed healing and wound disruption were common. A low vitamin C reserve is comparatively frequent in charity patients with intestinal diseases such as carcinoma of the stomach. For example, 40 per cent of a series of 90 patients with intestinal lesions (chosen consecutively) at the Illinois Research Hospital had a blood cevitamic acid level below 0.40 mg. per 100 ml. of blood (normal—0.70 to 1.0). This high incidence emphasizes the importance of giving fruit juices or cevitamic acid to such patients. Moreover, Lund, (9) has shown that celiotomies deplete this level still further, at least for a period of four to six days. According to Dunphy and associates (7), the basic defect in delayed healing in vitamin C deficiency is related to collagen synthesis; "mucopolysaccharide production and the formation of reticular procollagen material are not inhibited, and may be considerably increased."

Years ago, Clark (10) and Harvey and Howes (11) demonstrated that in protein deficiency wound healing is impaired. The relationship of tissue and blood protein to wound healing and various surgical complications has been reviewed by Ravdin and Gimbel (12). More recently Udupa and associates (13) have shown experimentally that in hypoproteinemia the "major factors in this impairment of wound repair appear to be the decreased accumulation of mucopolysaccharides and retarded collagen synthesis." When they added methionine to the protein-free diet fed their animals, mucopolysaccharides and formation of new collagen fibers were restored to normal levels.

Types of Healing. The healing of wounds may be classified as *primary* (*first intention*) *or secondary* (*healing by second intention*).

Healing by *first intention* (Fig. 8) takes place in a closed wound and occurs without infection or without secondary opening to remove blood, serum, or other fluid collecting in it. Accordingly, this represents ideal healing, although a mild degree of erythema, edema, or discoloration may be present. These manifestations, including mild induration, are encountered in wounds healing under optimum circumstances. Obviously, residual effects, such as scar tissue and disability, following healing by first intention are minimal or absent.



Fig. 6. Granulating wound after complete "full-thickness" loss of skin. The original injury was a severe burn of the axilla involving all layers of the skin (third degree); the necrotic tissue has already sloughed away. Spontaneous healing is too uncertain and slow in such a wound and skin grafting was done.

Dunphy and associates (6, 7) have shown that during this lag period certain important chemical and histologic changes are taking place. They demonstrated a marked concentration of hexosamine and mucopolysaccharides in the wound during this period. The hydroxyproline content of the wound was very low for three days following operation, but there was a rapid rise between the sixth and twelfth days. Hexosamine may be considered an index of ground substance and hydroxyproline of collagen. From the sixth day onward (in the normally healing wound), tensile strength increases rapidly. The end result of fibroplasia is scar (Fig. 7) or cicatricial tissue which accounts in part for the ten-

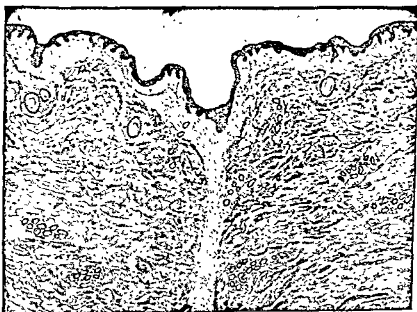


Fig. 7. Microscopic section through a healed surgical incision of the abdominal wall. Note the thin scar binding the two parts of the divided normal tissue. (From MacCallum. Textbook of Pathology, W. B. Saunders.)



Fig. 10. Hematoma of arm and face following a fall three days previously. Left, hematoma of medial side of upper forearm; right, contusion of nose with moderate swelling. As often happens following injury in this area, a hematoma developed under each eye.

frequently erroneously diagnosed as a depressed fracture of the skull. Occasionally a hematoma becomes infected, producing an abscess, but this usually happens when it is associated with a punctured wound; infection, however, may on rare occasions arise from blood-borne bacteria, as illustrated in Figure 11.

The immediate *treatment* of contusions consists primarily of the application of pressure and cold packs to stop the hemorrhage and extravasation. Rest of the injured part is essential to obtain optimum healing. After 24 hours the application of heat will facilitate because it produces an increased blood supply. When the laceration of subcutaneous tissue has been extensive, such as encountered in crushing injuries, extensive contracture due to scar or atrophy of important structures may develop. Wisely supervised active and passive motion may be useful in preventing these complications. When an injury is of the crushing type and severe, the patient should be examined for shock, which is apt to develop very rapidly after the patient is removed from the mechanism producing the injury; therapy is described on page 257.

If a hematoma forms and does not subside within a few days, an attempt should be made to aspirate it. If evacuation is not possible by aspiration, as commonly is the case because a variable amount of the blood is clotted, a small incision (under local an-



Fig. 11. Infected hematoma. This boy sustained an injury to the side of the head in a fall, resulting in a hematoma above the ear. Pain and tenderness decreased, but in two or three days became mildly intensified; doubtful fluctuation but no redness was present. Aspiration of the swollen area yielded pus; incision was carried out as indicated by the dotted line. Culture revealed streptococcus. Infection may develop in hematomas anywhere on the body, but is relatively uncommon; the organisms may gain entrance spontaneously (via blood stream) or through microscopic punctured wounds or lacerations.

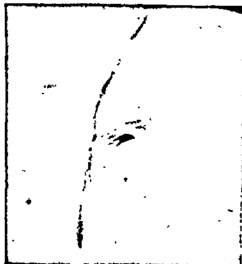


Fig. 8. Healing by first intention. The abdominal incision was made two months previously for the removal of a diseased gallbladder in a 78-year-old woman.

Healing by *second intention* (Fig. 9) is a term used to designate impairment of healing following infection, wound separation, or a collection of fluid which requires surgical opening of the wound. As a consequence of this complication, granulation tissue forms and healing is delayed. Open wounds which are allowed to heal without closure do so by secondary intention regardless of the presence or absence of infection. Fresh open wounds closed by a skin graft can heal by primary intention unless drainage develops spontaneously following surgical opening.

Healing by *third intention* is a term not universally recognized, but which is used to define healing following delayed closure or following application of a skin graft to a granulating surface; the term is applied regardless of the presence or absence of suppuration or drainage.

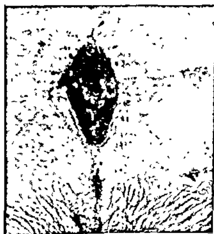


Fig. 9. Healing by secondary intention. The upper portion of a low mid-line incision for the performance of a gynecological operation became infected and is healing by granulation tissue.

TYPES OF WOUNDS

Contusions. A contusion or bruise is an injury of the subcutaneous tissue usually inflicted by a blunt object. There is frequently laceration of the soft tissues beneath the skin, but it may be of microscopic character. The injury of the overlying skin or mucous membrane is usually trivial and not great enough to allow the entrance of bacteria.

The *clinical manifestations* of contusions vary considerably, but in general they are much less pronounced than those observed in open wounds (see page 266). Pain is experienced immediately unless it is masked by excitement, traumatic shock, or unconsciousness. Swelling, tenderness, and ecchymosis are almost constant features of contusions except the minor ones. The pain usually subsides and disappears within 24 hours, except that movements of the injured part may create pain for 7 to 10 days, until healing of the tissues takes place. However, there are many complicating features of severe contusions, such as those produced by fracture and injuries to ligaments (sprains) and tendons, in which pain upon motion may be prolonged for weeks. Blood vessels are invariably severed except in the minor injuries and give rise to subcutaneous hemorrhage. If the hemorrhage arises from small vessels, the blood will infiltrate the tissues, perhaps becoming visible as a "black and blue" spot of the skin; this is known as ecchymosis. If the blood does not infiltrate the tissue but remains localized in a circumscribed manner, it is known as a hematoma. A hematoma (Fig. 10) may be palpated as an indurated or fluctuant area which frequently is absorbed very slowly. The blood may clot but usually remains liquid, day by day becoming darker and more viscid until, after several days, it is so thick that it cannot be aspirated through a needle of the type used in venipuncture (i.e., Nos. 19 and 20). When a subaponeurotic hematoma forms in the scalp, the edges become raised and indurated, and the injury is

tosis and fever will develop shortly after massive wounds are inflicted. Likewise, massive wounds with severe hemorrhage will result in traumatic shock (see Ch. 13) and anemia; the former develops immediately whereas the latter does not develop for 12 to 36 hours because time is required for blood dilution, as discussed in Chapter 13. There may be many complicating features of serious wounds, such as disability and deformity depending upon the structures damaged (e.g., fracture, torn ligaments, and lacerated nerves); the disability may be produced by pain as well as by damaged structures. After repair of the wound, pain usually disappears in 24 to 48 hours, but the tenderness remains for days.

Superficial wounds. Under this heading are included only those wounds which involve the skin and subcutaneous tissue to such a slight extent that suture is not required. Even though all layers of the skin may not be penetrated, a serious and even fatal infection may develop, usually due to a streptococcus and beginning as a lymphangitis of cellulitis. Therefore, the most important element in the treatment is the prevention of serious infections.

Treatment. Because of the danger of serious infection, all superficial wounds should be treated immediately after the injury and as many of the contaminating organisms eradicated as is possible. If a wound bleeds, the blood tends to wash out clumps of bacteria and foreign particles and is therefore an aid to aseptic healing. Local application of antiseptics to open wounds is in general to be condemned because of possible damage to tissue cells.

Abrasions should be washed gently with soap and water if the injured area is dirty. A dry sterile dressing is then applied. Local applications are not advisable except perhaps sterile petrolatum which may prevent the dressing from sticking. Cinders and other particles imbedded in a superficial abrasion may be removed advantageously by scrubbing with a brush after an anesthetic has been administered. This is particularly important when the wound is over the face because it will minimize subsequent cosmetic blemishes.

Superficial and short lacerations may be closed conveniently and the edges approximated by the application of a strip of adhesive tape which has been "flamed." If such a wound occurs on the face, however, it will usually be advisable to apply sutures since less scar will result from the better approximation. Regardless of the depth of the wound, if it is known to contain foreign material it must be opened and the debris removed.

In *punctured wounds* dirt and foreign bodies may be retained because of the small opening and lack of bleeding. These wounds are, therefore, more apt to become infected. Although on certain occasions it might appear wise to open and cleanse them, this is not advised as a routine. Such additional injury adds to the inflammatory reaction and may also spread the bacteria. Moreover, it is known that, after infliction of such a wound, bacteria are taken up by the lymphatics quite rapidly and travel far beyond reach of any antiseptic within a very short time following the puncture. It is *very important that rest be obtained* to combat infection and encourage healing. A punctured wound on the sole of the foot produced by a rusty nail, for example, is much more apt to become infected if the patient is allowed to walk. Punctured wounds in general are most prone to produce tetanus (see Ch. 7); for that reason it is more necessary to give a prophylactic dose of antitetanic serum of at least 1,500 units. It should be emphasized that it is not the rust itself, but the foreign bodies and bacteria on the rusty nail which are responsible for the infection.

Deep Wounds. The most important symptoms and signs of wounds have been discussed earlier in this chapter. However, certain manifestations will be presented in more detail under the various steps in the treatment taken up below; they are, as far as possible, in chronologic order. Before the local wound is repaired, the patient must be *thoroughly examined* for other injuries, some of which may prove much more serious than the local wound. War wounds are discussed in detail in Chapter 42.

TREATMENT OF OPEN WOUNDS
GENERAL PRINCIPLES

To minimize infection and facilitate rapid healing, numerous important principles must be utilized in the treatment of all serious

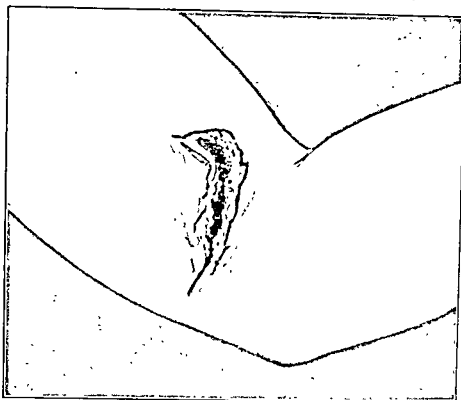


Fig. 12. Deep lacerated wounds of this type are sustained by relatively blunt objects. Because of the jagged edges, traumatized tissue, and contamination, débridement is an important feature in their treatment.

esthesia) may be necessary. After evacuation of the clot, a pressure dressing is applied to eliminate the resultant dead space; it is usually advisable not to close the small incision made for this purpose.

Open Wounds. There are many types of open wounds. An *abrasion* consists of a tearing or cutting of the superficial layers of the epithelium and is associated with an effusion of serum or a slight amount of capillary bleeding. *Punctured wounds* are made by sharp objects and may be comparatively deep, although the surface wound may be very small. *Lacerated wounds* (Fig. 12), are produced by dull objects and present torn and uneven edges. An *incised wound* is produced by a sharp object and presents smooth, even edges. A wound is considered *penetrating* when it enters a body cavity; it is classified as *perforating* when it penetrates the entire body. A *contaminated* wound is one which contains organisms, but in which sufficient time has not elapsed for the body tissues to kill the bacteria or for an infection to develop. Practically all open wounds sustained outside the operating room are contaminated. An *infected* wound implies previous contamination and sufficient lapse of time since injury to have allowed the invasion of the tissue by the bacteria and the development of the manifestation of infection. *Avulsions* are wounds in which a portion of the body has been torn away. The scalp and extremities are most often involved. The edges of such wounds are practically always uneven and jagged, due to the tearing of tissue. When an extremity such as the arm is avulsed, shock may be considerable, but fatal hemorrhage does not always ensue because of the rapidity of clotting in torn vessels. Chemical and thermal agents may also produce wounds which, because of their specific nature, are discussed elsewhere (see Ch. 15). Open wounds may be classified as superficial or deep.

Of the *clinical manifestations,* hemorrhage is perhaps the most important; all open wounds bleed, the amount varying with the extent of the wound and the size of the vessels torn. Tenderness and pain are constant unless masked by excitement, traumatic shock, or unconsciousness. After an hour or two, swelling is manifested; ecchymosis about the wound edges will be variable. Mild leukocy-

13. *Apply Proper Emphasis on Rest.* Although early ambulation after operation is conducive to rapid convalescence in many types of wounds, it does not apply to wounds of the lower extremity. This is due to the impairment in blood flow from the leg when in the dependent position. A patient with a major wound of the leg should not be allowed up until healing is nearly complete.

14. *Utilize Dressings for Specific Purposes.* The purpose of a dressing is to protect the wound from outside contamination and to absorb secretions. Keeping the uninfected wound dry encourages optimum healing. Because of the danger of contamination during a change of dressings, they should be changed infrequently unless pain or unexplained fever develops or they become soiled.

SPECIFIC DETAILS

Under this heading will be included the actual technical procedures utilized in the treatment of wounds; in general they are discussed in the order in which they will usually be employed in practice.

1. *Control of Hemorrhage.* Control of active hemorrhage is so urgent that it usually is a part of first aid treatment. Usually, all that is necessary is to apply pressure or to resort to a gauze pack and apply a light dressing over it. If the bleeding site is in an extremity, elevation thereof will often lead to cessation of the hemorrhage. Pressure over the wound may have to be maintained for several minutes to allow the development of a clot in the lumina of the severed vessels. If the bleeding is an ooze from innumerable points, the application of hot moist packs may be effective. On the other hand, if a large artery has been severed, it will be necessary to isolate the vessel, clamp it, and ligate it (perhaps proximal to the site of laceration) when definitive therapy is being carried out later in the operating room. When large vessels of this type are severed, first aid treatment by a pressure bandage may not control the bleeding. Under such circumstances it may be necessary to apply a tourniquet until definitive treatment can be carried out. To minimize deleterious changes from ischemia it is desirable to release the tourniquet for a moment every 20 or 30 minutes, but this procedure is usually associated with the loss of so much blood that it is inadvisable. However, the *tourniquet will have to be released* at the end of two hours, lest the ischemia lead to gangrene; it should be released only by a physician who should apply enough pressure at the bleeding point to minimize the blood loss during the "flushing" of the limb. A *tourniquet must never be applied* much tighter than necessary to obstruct arterial flow, lest the nerve trunks be injured, thereby resulting in a subsequent paralysis. Whenever convenient, a blood pressure cuff should be used as the tourniquet since the amount of pressure can in that way be controlled accurately. In spite of all precautions *tourniquets are potentially very dangerous* (see also page 252). If ample dressings are available and are applied with the proper amount of tension, a tourniquet need be used only on exceptional occasions. For example, a battalion surgeon (Capt. Lawrence Mann) who went through the bloody attack on Omaha beach on D day in Normandy in World War II found it necessary to use a tourniquet only once during the entire attack which lasted several days. On this one occasion it could have been avoided but was placed at the end of a stump after destruction of the distal portion of the extremity by an exploding shell; used in this way it can harm only the slight amount of tissue remaining distal to the tourniquet.

Although numerous hemostatic agents (fibrin foam, oxidized cotton or gauze, and gelatin sponge) have been made available during recent years, *only one, the gelatin* sponge (Jenkins and associates, 14), is receiving wide usage at the present time. It is used chiefly during major operations when the bleeding vessels cannot be reached for ligation, when its ligation might lead to serious ischemic effects, or when uncontrollable bleeding occurs in parenchymatous organs such as the liver, spleen, or kidney. It should be emphasized that none of the hemostatic agents will control hemorrhage from a large artery but are most useful in controlling mild hemorrhage from inaccessible points or from brain and bone tissue. However, the gelatin sponge is very effective in controlling hemorrhage from large veins. All tend to encourage slightly the growth of bacteria. All are soluble and need not be removed.

wounds. The surgeon must be so familiar with these principles that he utilizes them automatically; failure to recognize the importance of these principles may result in failure, and perhaps even in the death of the patient.

1. *Maintain Aseptic Technic.* All personnel working in or about the operating room must adopt routines and habits which will prevent infection. Caps and efficient masks must be worn at all times by patients as well as by operating personnel. Coughing, sneezing, and clearing of the throat are prohibited in the operating room. The skin must be properly prepared (e.g., soap, water, and alcohol) and draped to exclude skin from the field after the incision is made. Utilization of instruments wherever possible, instead of fingers, for manipulation in the wound will minimize contamination. All personnel should develop an automatic conduct which will abolish breaks in technic (see page 63).

2. *Maintain Gentleness at All Times.* The surgeon must learn to be kind and gentle to tissue at all times, since rough manipulations give rise to hemorrhage, exudation, and infection; even though infection fails to develop, healing is impaired.

3. *Use Small Instruments.* The use of small instruments, particularly hemostats, and ligature of small bites of tissue in tying bleeding points will result in much less trauma to tissue. For ligating vessels some surgeons rely on transfixing sutures which are tied just tight enough to stop bleeding but not tight enough to cause necrosis.

4. *Utilize Sharp Dissection Wherever Possible.* Dissect tissues with the knife, utilizing the scissors or hemostat only when safety indicates. At all times use a knife (not scissors) to cut or trim skin.

5. *Keep Tissues Moist.* When a large amount of raw tissue is exposed, keep a sponge moist with warm saline on the area where the surgeon is not working; this prevents drying, which is very harmful.

6. *Minimize Blood Loss; Replace That Lost.* As the surgeon cuts through the tissue, the assistant must rapidly clamp all bleeding points because the amount lost in the discarded sponges is always greater than anticipated. During recent years it has been demonstrated that liberal replacement of blood loss will permit much more extensive procedures with greater safety than was previously considered possible.

7. *Use Fine Nonabsorbable Sutures Wherever Possible.* All sutures should be as fine as is consistent with the strength required. When a suture fails to hold, it is usually because it has pulled or cut through the tissue and not because it broke. Nonabsorbable sutures incite much less tissue damage than catgut. Atraumatic needles are preferred, particularly when suturing delicate structure such as the intestinal wall and blood vessels.

8. *Leave No Devascularized Tissue in the Wound.* This precaution applies to wounds made in the operating room as well as to accidental traumatic wounds. Devascularized tissue always encourages development of infection, particularly gas gangrene.

9. *Avoid Dead Space and Tension.* Any dead space soon becomes filled with serum in which bacteria tend to grow. Tension is very undesirable because it interferes with normal blood flow through the area and, likewise, tends to make the suture cut through the tissue, thereby encouraging wound dehiscence. At times it may be disastrous; e.g., undue tension on an intestinal suture line almost always will result in the suture cutting through, thus creating a leak.

10. *Save All Skin Possible.* No skin should be sacrificed needlessly, particularly if the patient has had an accident which has already resulted in loss of skin. Of more importance is the fact that sacrifice of skin will result in poor closure with tension and, perhaps, poor healing.

11. *Minimize the Use of Drains.* The indiscriminate use of drains, particularly those left in place for many days, is to be condemned because drains produce open wounds which encourage infection by contamination from the outside.

12. *Do Not Attempt to Substitute Chemotherapy for Good Surgery.* Chemotherapeutic agents are wonderful aids to the surgeon, but they will not act as substitutes for good surgery. Failure to observe the rules described above is apt to result in infection in spite of penicillin or sulfonamides. Moreover, once an abscess has formed, chemotherapy will not eliminate the necessity of drainage although it will minimize the spread of the infection.

are to be suspected and appropriate examinations carried out.

4. *Antisepsis.* Prevention of infection is actually best promoted primarily by mechanical cleansing, which is the most effective method of eliminating contamination. Cleansing of the skin around the wound is of preliminary importance in order to prevent further subsequent contamination therefrom. There is probably no better method of cleansing the skin than the proper gentle yet thorough use of soap and warm water. A fat solvent such as benzene or ether may be needed if a considerable amount of grease is present on the skin. The importance of antiseptics in the treatment of wounds has been greatly exaggerated, particularly because it is only a matter of a few minutes or an hour following injury until the organisms will penetrate the tissues deeply enough to prevent their destruction by the surface application of an antiseptic. Most antiseptics also inflict severe damage to the tissue cells of an open wound and in that way interfere with healing and also tend to promote infection.

5. *Anesthesia.* Some type of anesthesia is nearly always necessary in the closure of wounds. The facility of closure and débridement depends to a certain extent on the presence of good anesthesia. Choice of the anesthetic is important. Good anesthesia allows a more thorough exploration of the wound for foreign bodies, severed tendons, and nerves, and a more careful approximation of tissues. If the patient is composed and the wound small, a local anesthetic (0.5 per cent procaine) may be used; otherwise, a general anesthetic is preferable, unless the patient has eaten a significant amount of food less than two or three hours previously. A preliminary dose of morphine, hypodermically, is usually advisable regardless of whether a local or general anesthetic is used. When a general anesthetic such as ether is to be given, it is advisable to add atropine or scopolamine to the morphine in order to dry up the respiratory secretion stimulated by the anesthesia. If intracranial or intrathoracic injuries are also present, it may be imperative to use a local anesthetic even for the repair of an extensive wound because of the damage which might be inflicted on the circulation and the respiration by general anesthesia.

6. *Débridement and Closure of the Wound.* Under ideal conditions this can be carried out with full expectation of primary healing. Unfortunately, closure of the wound is not always possible. For example, *in war wounds primary closure is unsafe* (see Ch. 42). The decision as to whether a wound is 1. to be closed by primary suture, or 2. to be closed around a drain, 3. to be closed later by secondary suture, or 4. to be allowed to heal by granulation without suture depends to a large extent on the presence or likelihood of infection, which is governed by many factors. The most important factor is the *length of time which has elapsed between the injury and treatment.* In general, wounds over 24 hours old are considered too deeply invaded by bacteria to permit primary closure, although it appears that, if antibiotics (e.g., penicillin) had been given during this interval preceding repair, débridement may be done safely even though more than 24 hours may have elapsed since injury; those under 8 hours are nearly always suitable for immediate suture. In wounds between 8 and 24 hours old, the appearance and type of the wound, the probable amount of contamination, the extent of the inflammatory signs, as well as the factors mentioned below, determine the question of closure and drainage. Another important factor is the amount of traumatized tissues, dirt, and debris in the wound. In wounds treated early and effectively, however, the relation of these factors to infection and delayed healing can be eliminated in most instances by *débridement.* This consists of excision of all badly contaminated, devitalized, or jagged tissue, and the removal of all foreign bodies by careful and painstaking exploration of the injured tissue. To be properly done, débridement of the deeper portions of the wound should be done with a second set of sterile instruments.

Débridement or wound excision is the most important phase in the treatment of the wound. The primary objective is to remove all devitalized tissue and foreign bodies, with removal of minimal amount of viable clean tissue (Fig. 13). Wound excision need not be a block excision; in fact, it is advisable to excise portions of devitalized tissue at one time so that needless sacrifice of healthy tissue can be avoided. Each anatomic struc-

Until a few years ago, the true significance of loss of blood at operation or from injury was not fully appreciated. While the blood loss during débridement of a wound will rarely be serious, blood loss in accidental wounds immediately after injury may be sufficient to cause shock or death. Although not all the blood loss during optional operations, such as celiotomies, can be considered preventable, the surgeon should be aware of it, and should replace significant losses by transfusions even if no signs of shock are present. The magnitude of blood loss can readily be measured by analyzing the blood in the discarded sponges and is practically always greater than anticipated. For example, Coller and associates (15) found that the average blood loss in brain operations was 1,084 ml., in radical mastectomies, 732 ml., but in hernia operations only 74 ml. This illustrates that, when a large blood loss is expected, transfusions must be given during or immediately after operation.

When bleeding is not controlled by the usual means, i.e., by ligation of bleeding points and by pressure, one must consider the possibility of abnormal or disease processes. Occasionally such hematopoietic diseases as hemophilia (deficiency of thromboplastic substances—hereditary) and thrombocytopenic purpura (deficiency of platelets) will explain the hemorrhage. Transfusion of fresh blood is quite effective temporarily in these two conditions; platelet transfusions, which require a lot of fresh blood, are more effective temporarily than transfusions of whole blood for the latter condition. Prothrombin deficiency (caused particularly by hepatic insufficiency) should be thought of as a possible explanation, especially if the patient is jaundiced; vitamin K-like products are quite effective except when hepatic insufficiency is severe. At times the bleeding is caused by a transfusion reaction. Citrate toxicity after transfusion of many units of blood in a short time may perhaps result in bleeding, but proof is not clear; nevertheless, Allen (16) recommends giving 1 gm. of calcium gluconate (through a separate infusion set) after every second transfusion during surgery involving rapid blood loss. On rare occasions heparinoid anticoagulants or fibrinolysins explain the hemorrhage; continued transfusions appear to aggravate the bleeding in these conditions. For the former the intravenous injection of 100 mg. of protamine sulfate or 200 mg. of toluidine blue is quite effective. If hypofibrinogenemia is suspected, blood should be drawn for fibrinogen levels; a concentration below 175 mg. per cent is usually sufficiently low to justify initiation of fibrinogen therapy (17).

2. *Treatment of Shock.* If shock is present, it should be treated almost simultaneously with the control of hemorrhage; such therapeutic measures as elevating the foot of the bed and administration of physiologic saline and glucose intravenously, as well as transfusion of blood, must be instituted (see Ch. 13). However, the patient may present many of the symptoms and signs of shock, including pallor, cold sweat, vertigo, and weak pulse, but may actually be suffering merely from a "fainting attack." It will rarely be difficult to differentiate a syncope of this type from true shock if one considers the severity of injury and the physical findings. Lowering the head and inhalation of aromatic spirits of ammonia will be sufficient to combat syncope.

3. *Examination of the Wound.* This should be carried out soon after the bleeding has been controlled and shock and syncope have been treated. The wound is inspected for the possible presence of foreign bodies unless their presence can be excluded by the history. Injury to the nerves and tendons may be detected by inspection of the wound for cut ends, but a more reliable method is to examine the part of the extremity distal to the wound. *A careful sensory and motor examination must be made.* Disability in the movement of parts distal to the wound may be due to severed nerves, tendons, ligaments, or muscles. Identification of the structure damaged is determined by the location of the wound, the type of disability, and inspection of the depth of the wound. Examination should also be made for the possibility of fracture of bones (see Chapter 22). If a fracture is suspected, roentgenograms may be advisable. If the wound is located over the torso, the possibility of internal injuries must be considered; if it is present over the skull, intracranial trauma and fracture of the skull

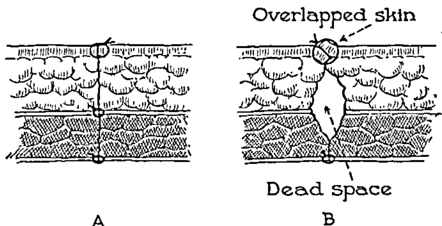


Fig. 14. Suture of a wound in layers. A, correct way to close a wound; B, incorrect way to close a wound; note the dead space in the subcutaneous tissue and the overlapping of skin edges.

trolled since blood clots encourage infection. If primary healing is excepted, nonabsorbable sutures (e.g., cotton or silk) should be used because less reaction is produced by them than by absorbable sutures (catgut); infection is therefore minimized.

After débridement is completed, the wound is closed, unless it is a war wound or is very badly contaminated with perhaps 12 to 24 hours intervening since infliction. Layer closure should be carried out if at all possible. The edges of the wound (deep and superficial) must be approximated to avoid a dead space and subsequent infection or collection of serum (Fig. 14). There must be no tension on the closing sutures; if there is, necrosis of tissue will result, and the sutures may cut through with formation of a dead space. The meticulous technic advocated by Mason (20) for wounds of the hand should be utilized in the care of all wounds (Fig. 15).

In the repair of wounds, it should be emphasized that only mesothelial surfaces will grow together. Muscle unites to muscle only by union of the fibrous tissue strands about the muscle bundles. Fatty tissue likewise unites only by union of the fibrous tissue contained in it. The best closure of a wound is obtained, therefore, when fibrous structures

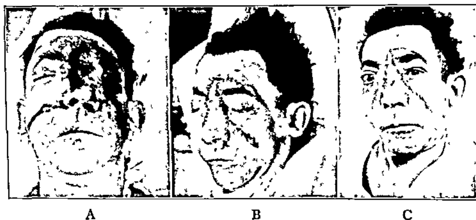


Fig. 15. Severe laceration of the face. A, photo on admission. The wound is associated with an unusual amount of trauma to the subcutaneous tissue; B, appearance of wound after débridement and closure with interrupted suture of horsehair; C, appearance of scar 10 days after accident. The mass to the right of the nose represents an enchondroma, present before the accident and not associated with the trauma. (St. Louis City Hospital.)

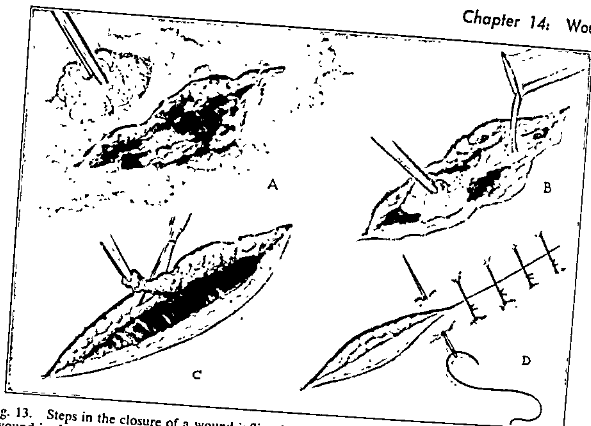


Fig. 13. Steps in the closure of a wound inflicted outside the operating room. A, the area surrounding the wound is cleansed with soap and water; B, the wound is irrigated with physiologic saline solution; C, débridement is performed, excising all traumatized and contaminated tissue. Subcutaneous interrupted sutures (usually silk) may be necessary to obtain approximation and eliminate dead space; D, the skin is closed with interrupted or continuous silk or horsehair sutures. Interrupted sutures of horsehair, nylon, or tantalum are commonly used on the face.

ture must be examined carefully and the line of excision determined by viability and presence or absence of foreign bodies. All devitalized skin should be excised. Trial excisions are carried out until a normal color and capillary bleeding are encountered. Devitalized muscle can be identified by its purple-red appearance and by its failure to contract when it is pinched. When devitalized muscle is incised, dark blood may escape; this is in contrast to bright blood which escapes in greater quantity when viable muscle is cut. Fascia is excised until a healthy surface is found. Tendons should be sacrificed only if seriously damaged or if foreign material is ground into them. Excision of nerve tissue must also be minimal. All veins in the extremities can be sacrificed, but certain arteries (e.g., popliteal) must be preserved if at all possible to prevent gangrene of the distal extremity; if such an artery is destroyed, a graft is usually advisable.

There is disagreement as to whether or not wounds should be irrigated before or after débridement. In reality, this question should be determined by certain conditions. For example, if the contamination is limited to a small area near the surface, it is better not to irrigate the wound because the deeper uncontaminated portion might then become contaminated. On the other hand if the entire wound is contaminated, irrigation is desirable. From the experimental standpoint, irrigation results in better healing in contaminated wounds, providing it is done *gently* (Peterson, 18).

The technic used during débridement must be of the Halsted (19) type, i.e., performed with gentleness and minimum trauma, and by using small ligatures and instruments. Bleeding points must be searched for and controlled by small artery forceps applied to the vessel with minimal tissue surrounding it. If the bleeding point cannot be controlled with the inclusion of a minimal amount of tissue, a transfixing suture should be inserted and a ligature tied just tight enough to stop the bleeding. Bleeding points must be con-

time when children are immunized against childhood diseases. If antitoxin is given (e.g., after infliction of a contaminated wound), it is best to allow an interval of several weeks to elapse before giving toxoid. For details of the use of tetanus antitoxin see Chapter 7.

8. *Chemotherapy*. Certain drugs may be very helpful in the prophylactic control of infection as well as in the treatment of an active infection but should never be used as a substitute for good surgery. Since a contaminated wound is apt to contain numerous organisms, more than one antibiotic is indicated in prophylaxis, as well as in treatment, in order to attain as wide a range of antibacterial action as possible. Of all agents, penicillin is perhaps the most important, largely because it is most effective against the streptococcus, which is probably the most serious of the common invaders. However, certain strains of staphylococci, which are perhaps the most common of the wound contaminants, are either resistant to penicillin or *develop resistance* to it. Moreover, penicillin is not very effective against the gram-negative organisms. Bloemers and Kempf (23) found streptomycin much more effective against *E. coli* (in peritonitis) than penicillin, and an additive though not synergistic effect when the two drugs were given together. However, aureomycin and chloromycetin are even more effective against gram-negative organisms than is streptomycin. These drugs are also strongly indicated in the presence of pyogenic organisms (especially staphylococci) which are not sensitive to penicillin. Although prophylactic chemotherapy has certain merits, Altemeier and associates (24) have very aptly summarized the disadvantages; some of these are the development of resistant strains of bacteria, production of a false sense of security on the part of the surgeon, and masking of the signs of infection.

Not all wounds are contaminated sufficiently to justify the prophylactic use of antibiotics. The factors which influence this decision are the amount of contamination, the time interval between injury and repair, the amount of damaged tissue, and the technic of repair. If administered, they should be continued for three or four days. The prophylactic dose is ordinarily less than the therapeutic dose. For detailed discussion of chemotherapy see Chapter 5.

Suture of Special Structures. When a major *nerve* has been severed it should be repaired. Before approximation, the severed ends, if jagged, should be cut across cleanly with a sharp knife. Two sutures of fine silk should be sufficient to maintain end-to-end approximation (some surgeons use fine tantalum wire as sutures). The stitch should be of the mattress type and be taken deep enough to include only the epineurium. Care should be exercised in approximating the ends in order to avoid rotation which would delay or prevent regeneration. In massive war wounds which are débrided and packed open (not closed), divided peripheral nerves are not repaired immediately, but should be approximated with a fine wire suture in order to prevent retraction, thereby facilitating second stage repair later. Details of nerve injuries may be found in Chapters 17 and 27

When *tendons* of the wrist or hand are severed, primary suture is advisable only when aseptic healing is certain. A severe infection in the presence of the repaired tendons usually results in a failure of maintenance of approximation and the development of a contracture. Years ago Koch (1931) showed that if there is a strong probability of wound infection because of a long period intervening between injury and repair, it is better to close the wound and perform the tenorrhaphy at a later date. Koch emphasized the fact that infection of the wound following repair of a tendon surrounded by a sheath is much more apt to result in a permanent contracture (because of the spread of the infection throughout the sheath) than when the sheath is absent. He concluded further that, as a rule, if more than four hours have elapsed since injury to a palmar tendon, it is wiser to close the wound and perform the tenorrhaphy after the wound has healed. The decision as to repair of the tendons must be made by the surgeon, depending upon the type of wound, because in many instances, if the wound has been made by a clean, sharp object and properly cared for, repair of tendons may be successful when six to eight hours have elapsed following injury, particularly since the ad-

can be approximated. A drain is rarely indicated unless hemostasis has been unsatisfactory or a dead space could not be obliterated; in such a case, it may be removed in 24 hours. For closing the skin, interrupted or continuous sutures of fine cotton or silk are usually used, but, on the face, where a minimal scar is desired, some type of suture with a surface which is impermeable to moisture (e.g., horsehair, dermal, and nylon) will be superior, because less reaction is produced in the tissue about the suture. Interrupted sutures are usually used on the face. Details of suture material, drains, and infections are discussed elsewhere in this chapter.

If closure of the wound is not possible because of destruction of skin and subcutaneous tissue, a flap should be created to fill up the deficit, or a skin graft should be applied. In severely contaminated wounds immediate closure may be undesirable, but, after four or five days, secondary closure may be possible. Antibiotics are not routinely used, but, under such circumstances, they are indicated.

The principles just discussed in the treatment of accidental wounds can be applied to a great extent to *wounds made in the operating room*, the most important of which are *abdominal incisions*. Incisions in the abdominal wall should be oblique or transverse (21) whenever possible because postoperative strain is less likely to lead to disruption. Most surgeons use interrupted, nonabsorbable sutures to close the fascia of abdominal wounds on the assumption that less infection, wound disruption, and postoperative hernias will ensue. The skin adjacent to the wound should be covered with sterile drapes. The wound itself is by no means sterile, as has been demonstrated by numerous workers who have obtained positive cultures in practically 100 per cent of clean abdominal wounds made in the operating rooms. This is explained by the fact that such factors as the skin, the air, and improper masking are serious sources of contamination. During operation, all tissues including the intestine must be kept moist with sponges, because drying of tissue results in its death. Most surgeons who advocate nonabsorbable sutures prefer not to bury catgut in the same wound on the assumption that this increases the possibility of infection. Stay sutures are rarely necessary when abdominal wounds are closed with silk or cotton. To combat the development of infection in abdominal wounds contaminated by spillage during such procedures as colonic resections, gentle irrigation with physiologic saline may be instituted at the end of the operation. Antibiotics are not placed in the wound when contamination is sustained, but their use systemically may be very effective in lowering the incidence and severity of infection.

7. *Tetanus Antitoxin* (*A.T.S.*). This need not be given if the wound is small, superficial, and inflicted by a clean sharp object. In deep punctured wounds antitoxin is especially indicated, unless the wound has been caused by an instrument such as a clean, smooth needle. In localities where tetanus is prevalent because of such factors as extensive use of manure as fertilizer, administration of tetanus antitoxin as a routine may be indicated even in small wounds. It should always be given when the wound is extensive or contaminated with dirt and foreign bodies. A dose of at least 1,500 units, subcutaneously or intramuscularly, should be given. Some authorities (Spaeth) recommend much larger prophylactic doses. In gunshot wounds or in massive wounds inflicted in barnyards or in the streets, a dose of 5,000 to 10,000 units should be given. Since the immunity conferred by the administration of a dose of tetanus antitoxin *lasts no longer than 10 to 14 days*, it will be necessary to *repeat the prophylactic dose* if operative procedures about the original wound are contemplated more than two weeks after administration of tetanus antitoxin. In view of the marked prophylactic value of penicillin procaine in the development of tetanus experimentally (Taylor and Novak, 22), it is probably desirable to give this agent in large doses to patients having heavily contaminated wounds. If there is massive destruction of tissue with excessive contamination, a prophylactic dose of gas bacillus antitoxin should be given as well as tetanus antitoxin. Individuals (especially children) who are subject to frequent injury should be immunized actively with tetanus toxoid. This is now common practice at the

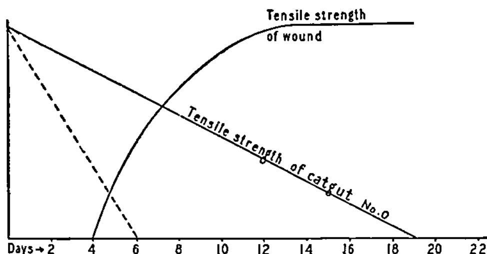


Fig. 16. Relation of decreasing tensile strength of catgut to increasing tensile strength of wound (healing under aseptic conditions). The broken line illustrates the rapid loss in tensile strength of even large catgut (No. 2, plain) in an infected wound. (Modified from Howes and Harvey. New England J. Med.)

a permanent foreign body and, in grossly infected wounds, does not lead to persistent drainage, as would be the case with nonabsorbable sutures. The *disadvantages* of catgut are that it can be sterilized less readily than silk and that a reaction in the tissue with a tendency toward development of infection follows its use; in a study of 2,360 inguinal herniotomies, Shambaugh noted that the incidence of suppuration was twice as great in those closed with catgut as it was in those closed with silk. Moreover, in the presence of infection its tensile strength decreases rapidly even though chromicized gut is used (Fig. 17). In the presence of infection, catgut delays healing. Jenkins and associates (26) have shown that many brands of catgut are preserved in chemicals which are extremely irritating to tissues. Unless the preservative is known to be harmless, all cat-

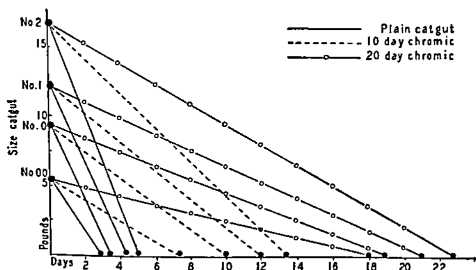


Fig. 17. Decrease in tensile strength of various sizes of catgut buried in a noninfected wound. Note that regardless of size, plain catgut (indicated by solid line) loses its tensile strength within five days, whereas, 20-day chromic catgut (indicated by line with circle) loses its tensile strength only after 18 days even in the finest (00) size. (From Howes and Harvey. New England J. Med.)

vent of penicillin. The slow rate of healing of injured tendons, which is probably dependent upon inadequate blood supply, demands secure fixation and approximation of the cut ends over a period of seven to twelve days. Therefore fine silk is the suture of choice since catgut may be absorbed too soon. Details of the treatment of severed tendons may be found in Chapter 17.

Any wound sustained over a *joint* should be closely inspected for possible laceration of the joint capsule. If an opening is found, it is imperative that the joint be inspected for foreign bodies and dirt, and, if present, these must be removed. Removal of debris is facilitated by irrigation with a solution such as physiologic saline. The wound in the joint capsule should then be closed by interrupted sutures of fine silk. The rest of the wound is closed in the routine fashion. It should be inspected daily, and the patient's temperature should be observed closely for the possible occurrence of infection within the joint. The presence or absence of pain about the joint is usually helpful in determining whether or not an infection has occurred. It is imperative to discover the infection as soon as it occurs so that the joint may be reopened and the chance of destruction of the cartilage minimized (see Chapter 24).

Sutures. There are numerous varieties of suture material in use at the present time. Many of them are merely substitutes for each other without obvious advantages or disadvantages. However, on certain occasions one type of suture will be superior, whereas on other occasions a distinctly different type of suture will have obvious advantages.

Types of Suture Material. Sutures are classified as absorbable and nonabsorbable. The latter type is not affected by the digestive action of body fluids and leukocytes and remains indefinitely, unless cast off or removed. Nonabsorbable sutures most commonly are of silk, but linen, nylon, cotton, dacron, orlon, silver wire, silkworm gut, and varieties of vegetable fiber (dermal) are also used under special conditions. Silk may be used in a variety of sizes from the finest, split strands to thick, braided cords. The advantages of silk lie in the fact that it does not lose its tensile strength, except to a slight degree, and holds the approximated structures together almost indefinitely. Silk provokes a minimum of tissue reaction in the absence of infection, and healing therefore is accompanied by very little scar tissue. Silk, moreover, has such intrinsic tensile strength that very fine strands are adequate to hold most structures in place. The *disadvantage of silk* is confined to its action in the presence of infection, for under such conditions it acts as a foreign body and, as already mentioned, will prevent healing until it is discharged. However, wounds closed with interrupted silk will tolerate contamination better than wounds closed with catgut, although if the wound does become infected some of the silk sutures will be extruded. Since the onset of World War II cotton is displacing silk to a great extent, although its tensile strength is not as constant as silk; it invokes perhaps even less reaction in tissues than does silk (Meade and Ochsner, 25). Practically all the other remarks made about silk apply also to cotton. Other nonabsorbable suture materials such as horsehair, linen, metal clips, dermal (vegetable fiber), and nylon are available but are used largely in the skin. In recent years two or three types of fine, pliable metallic sutures made of stainless steel and tantalum have been introduced. They are, of course, nonabsorbable, strong, and well-tolerated by tissues even in the presence of infection.

Absorbable sutures are those which are digested by the tissue juices and leukocytes and replaced by scar. Catgut is the most common representative of absorbable suture, but kangaroo tendon is sometimes used. Catgut is of animal origin, being prepared from the submucosa or fibrous layer of the terminal ileum of sheep. It is prepared in a variety of sizes, from the finest, No. 00000, to No. 2 or larger, which is quite stout. Slow absorbability is achieved by treating the material with various chemicals, usually potassium bichromate. Potassium mercuric iodide, tannic acid, and other chemicals are likewise used to decrease the absorbability. One *advantage* of catgut is that, as it is absorbed, scar tissue becomes deposited which binds the approximated structures together (Fig. 16). Since it is absorbed, it does not act as

the other hand, it is probably also true that if this same care in technic is utilized, fine catgut will give fairly satisfactory results. In other words, the "philosophy" of silk technic (including gentle handling of tissue, careful application of hemostats, and use of fine sutures), as originally developed by Halsted (19), *should be mastered by all surgeons and* will no doubt be responsible for much better results than a technic of careless and rough handling of tissue, which is bound to be detrimental to healing of wounds. The reason a great many competent surgeons still use catgut and are not inclined to change to silk lies in the fact that they are using silk "philosophy" in the use of catgut, and are, therefore, obtaining such good results that they see no reason to change. Unfortunately, this is not true in all instances.

Drains. Although drains are distinctly contraindicated when aseptic healing is expected, there are occasions when the closure of the wound around a drain is advisable. The use of drains in the repair of accidental (i.e., grossly contaminated) wounds is confined chiefly to two types: 1. in wounds where hemostasis could not be satisfactorily attained (under such circumstances the drain is removed in 12 to 24 hours when all bleeding has stopped), and 2. in wounds where dead space could not be effectively eliminated. Opinions differ considerably as to whether or not a drain should be left in wounds which are closed eight hours or more after the injury. Some surgeons are of the opinion that, if infection develops, the presence of a drain will help to keep the process localized and to produce fewer systemic or local manifestations. This is no doubt true, but it is also true that on numerous occasions the drain will act as a foreign body and aid in the development of an infection, whereas the wound would not have become infected if it had been closed without drainage. This is particularly true of wounds closed with catgut, since a catgut suture encourages the development of infection more than does a nonabsorbable suture. The argument cannot be settled by a dogmatic statement because it is impossible to predict which wound would or would not become infected. The use of drains in abscesses is discussed elsewhere.

A small strip of rubber dam is superior to almost any other type of drain and in most instances should be anchored with a suture to *prevent losing the drain* in the depth of the wound. The loss of the drain in the wound may also be prevented by attaching a safety pin to that portion outside the wound or by using such a large piece that it is impossible for the entire drain to be lost in the wound. When draining sma'l wounds a wick made of doubling several strands of catgut or silkworm gut may be adequate. When a penetrating and very extensive wound needs drainage, a large drain will, of course, be needed. Tubular drains made of soft rubber (Penrose) are splendid for this purpose. Rubber dam may be rolled up to the size desired and is very satisfactory because it is soft and pliable and, therefore, causes no pressure necrosis, which can be a serious complication, indeed, if the tissue involved is intestine.

In most instances, a drain left in a wound at time of closure may be removed in 24 or 48 hours. If a definite infection develops, it may be advisable to keep a drain in the wound for several days. The length of time is dependent upon such factors as the severity of the infection, the size of the cavity, and the efficiency of the drainage. Although gauze wicks or packs are very useful in stopping hemorrhage from the edges of the wound, they do not serve as drains because the mesh rapidly becomes plugged with fibrin. Gauze wicks or packs should be removed in 12 to 18 hours and a rubber drain should be inserted if drainage is desired for a longer period of time.

The use of large rubber tubing for drainage of wounds, as so often recommended, is in reality to be condemned, except for drainage of large cavities (e.g., empyema), because of the pressure necrosis which they are apt to produce.

Postoperative Care. On many occasions healing by *primary or secondary union is de*termined largely, if not entirely, by the postoperative care of the wound. If the wound is large, this treatment can best be carried out in a hospital. Hospitalization is likewise strongly indicated when a large vessel has

gut must be washed *thoroughly* before being used.

Application and Choice of Sutures. When a wound is superficial and the subcutaneous tissue is not gaping, closure of the skin with a continuous or interrupted suture of fine cotton or silk will suffice. Black silk may have a slight advantage over white because in most types of tissues it can be seen more readily. For approximation of the skin, other nonabsorbable material may be used, including cotton, linen, metal clips, metal sutures, nylon, and dermal sutures. If the wound is on the face, interrupted sutures of fine horsehair should be used since this type of suture encourages healing with the least amount of scar tissue. Because of the need for good cosmetic results in wounds of the face or scalp, these sutures may be removed on the second to the fourth day. Most of the nonabsorbable sutures mentioned above may also be used as subcutaneous sutures and, in fact, are preferred over catgut. The only precautions are that fine sizes should be used and no sutures should be placed immediately under the skin because, when they are placed too close to the skin, they tend to work out of the wound.

If an operation must be conducted through a frankly infected field, catgut is the suture of choice because it is absorbed and, therefore, does not tend to produce persistent drainage through foreign body action, as might be the case with nonabsorbable sutures.

Formerly, stay sutures were placed through all layers of the abdominal wall, in addition to the regular layer closure; however, there is fairly good evidence that they not only fail to prevent *wound disruption* but actually are harmful because of the ischemia produced at the point of constriction by the suture. Accordingly, stay sutures are rarely used for the closure of abdominal wounds (Fig. 18). Disruption of an abdominal wound is rarely caused by breakage of the sutures but usually develops because they cut through tissue. Wound disruption commonly occurs in patients with such maladies as jaundice and inoperable carcinoma, especially when the patients are undernourished. A severe strain on the suture line, caused by persistent cough, hiccup or retching, is also a common or important factor in *disruption*, which is discussed on page 281.

The advantages of silk over catgut in clean wounds have already been discussed in this chapter and are particularly valued and demonstrable in thyroidectomies and herniotomies. However, it is important to emphasize again that a much more careful technic is necessary if silk is to be used without the serious complication of the development of infection with persistent sinus formation. On

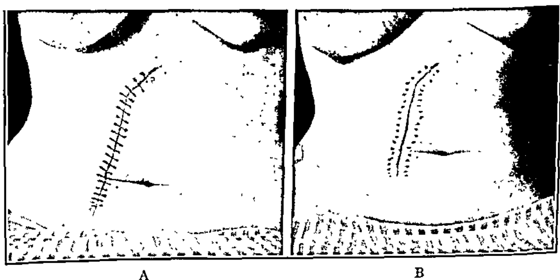


Fig. 18. Abdominal incision (laparotomy) healing per primam. A, five days after closure of skin with continuous cotton suture. B, ten days after operation. The sutures were removed on the seventh postoperative day.

tant to immobilize the extremity, including the joint, when the wound is located over the extensor surface of a joint. If the wound involves the joint capsule, complete immobilization is indicated until such time when the possibility of infection has been eliminated (four to eight days).

Removal of Sutures. The time for the removal of sutures depends in general on the rapidity of the fibroblastic reaction. There is a latent period of approximately four days before significant tensile strength develops. It is only after 10 to 14 days that this process reaches a level. Skin sutures, however, may be removed much earlier than this, i.e., five to seven days after injury, depending upon the location of the wound. In an area as vascular as the scalp, and in regions where little movement is present, sutures can be removed at the end of 48 hours, especially if subcutaneous interrupted stitches have been applied. On the face, which is likewise quite vascular, wounds also heal rapidly; some of the sutures (perhaps every other one) may be removed on the second day and the rest on the third day or fourth day, depending upon the condition of the wound. If they are left in place longer, the amount of scar formation is increased. Skin sutures should not be removed from a wound in a dependent position, such as the leg, earlier than the eighth postoperative day unless it is a very superficial wound. The dependent position and the movements associated with walking delay healing, and the wound edges are apt to separate if stitches are removed earlier than the eighth day. However, when the wound is not in a dependent position, ambulation appears to accelerate healing.

Symptomatic Treatment. Under this heading may be included numerous miscellaneous therapeutic measures, the chief ones of which are medicinal. On many occasions it may be advisable to prescribe a sedative (aspirin, codeine) for pain or discomfort, especially if the patient is nervous and easily excitable. If a local anesthetic (procaine) has been used there may be considerable burning for an hour or two while the effect of the anesthetic is wearing off. This may be relieved by a hot water bottle.

WOUND DEHISCENCE

Separation of wound edges may be due to many causes, which may be summarized as traumatic or nutritional. Patients who have persistent coughing (Fig. 19), vomiting, or hiccup after operation have a high incidence of disruption, particularly if the patients are jaundiced or have inoperable carcinoma. Age is also a factor, as indicated by the clinical study conducted by Marsh and associates (27); these investigators found that the average age of patients having dehiscence was 56 years compared to an average age of 48 in patients whose wounds did not disrupt. Dehiscence of abdominal wounds is most common between the eighth and twelfth days. The first evidence of disruption of an abdominal wound is often a sudden discharge of sanguinous fluid. Sudden development of anorexia in patients who have started to eat following celiotomy is often the first sign of a partial wound separation. Emergency closure is indicated in all patients with complete disruption and in most patients with partial separation. The edges of disrupted wounds reveal surprisingly little reaction, but when they are closed with through-and-through sutures, they heal remarkably well. In fact, Savlov and Dunphy (28) have shown experimentally that wounds which have disrupted and have been resutured actually heal more rapidly than those healing under normal circumstances.

CRUSHED WOUNDS

Obviously, crushed wounds of varying severity may be produced with or without destruction of the skin. One of the most frequent types of crushed wounds encountered at the present time is that inflicted by the electric wringer on the upper extremity (usually in children). However, fractures are rarely produced by this type of injury. The enormous amount of pressure exerted by the wringers produces a varying amount of permanent damage to the skin, subcutaneous tissue, and muscles (Fig. 20). Most of the damage to the skin is inflicted usually on the forearm at the point where the wringer stops (or perhaps spins). Not infrequently, the skin is damaged so much that ultimately (after a few days) it becomes gangrenous.

been severed and secondary hemorrhage is likely.

TYPES OF DRESSING. When the wound has been closed without drainage, nothing more than a sterile, dry, gauze dressing need be applied. If the wound is deep, or hemorrhage likely, it is usually advisable to apply a firm dressing so as to minimize the possibility of bleeding and the formation of a hematoma. Dry dressings have an obvious advantage over others in that the secretions which escape from the wound edges are rapidly absorbed by the gauze and bacteria which may be present in the secretion are killed or inhibited by drying. A dry dressing, likewise, allows the edges of the wound to adhere fairly firmly in 36 to 48 hours with the formation of a crust which seals the wound, thereby minimizing the possibility of infection from the exterior. Silver foil, partly because of its antiseptic qualities, is an excellent dressing and is used extensively over craniotomy wounds. Ointments are disadvantageous because they prevent drying and the formation of the protective crust, thereby encouraging the development of secondary infection. However, if the gauze sticks to the wound it will be necessary to apply a small amount of petrolatum or bland ointment to prevent pain and injury to the regenerating epithelium on the edge of the wound at subsequent dressings.

Gauze dressings may be anchored by adhesive or a bandage. A bandage is apt to be more comfortable and will assist in absorbing wound secretions but cannot be applied conveniently on the torso. On certain occasions when it is necessary to apply a small dressing (as on the scalp) the dressing may be anchored by collodion or liquid adhesive, which must be applied only on the edges of the dressing so as not to seal over the wound edge. It should be stated that some surgeons do not use dressings on clean wounds. However, the justification of this procedure is not yet proved.

TECHNIC OF DRESSINGS. In clean wounds dressings need not be changed until time for removal of sutures, unless evidence of infection or other complications develop. For example, the dressings on laparotomy wounds need not be changed until the sixth or seventh day, when the skin sutures are removed. This is a precaution taken to minimize secondary infection. However, if fever, pain, or leukocytosis develop, indicating the possible presence of infection, the dressing may be changed at any time. The dresser should wear a mask and pair of gloves; the latter need not be sterile but should be washed in soap and water between cases after contamination. At least two hours should elapse after sweeping floors before dressings are changed. If an indurated, reddened area is found suggesting the presence of an abscess, drainage will be indicated. Usually all that need be done is to remove a few sutures to allow spreading of the wound and evacuation of the pus. The opening in the wound should be enlarged so that practically the entire extent of the abscess is opened for drainage. Soft rubber drains can be inserted but are usually not necessary. Hot, wet dressings encourage drainage and healing. The treatment of infection is discussed later in this chapter.

If there is question as to the possible formation of a hematoma, or dead space, the dressings may be removed at any time indicated. With sterile gloves, or palpation over a sterile towel, the indurated area in the wound may be detected and the cavity drained. Drainage can be accomplished by insertion of an instrument through the suture line into the cavity, after first painting the area with a mild tincture of iodine or other nonirritating antiseptic to prevent contamination into the depths of the wound. Evacuation of the hematoma or dead space is usually sufficient to take care of the complication, but, if large, the cavity may be drained for 24 to 48 hours with a soft rubber drain. A pressure dressing may be very helpful.

IMMOBILIZATION. One of the most important features in the postoperative treatment of wounds is *immobilization of the injured part*. Any movements which allow the wound edges to become detached and traumatized will, of course, delay healing and may encourage the development of infection. If the wound is on the upper extremity, a sling may be sufficient to obtain this immobilization. If the wound is on the lower extremity, it may be necessary to confine the patient to bed for a few days. For obvious reasons, *it is impor-*

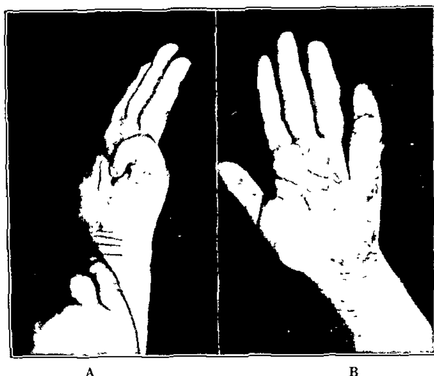


Fig. 20. Crushed wound producing flexion contracture of finger. A, two months after crushing of hand by an electric wringer; no open wound was sustained. B, the scar was excised, the finger released, and the resultant defect repaired by a "flap" skin graft removed from the inguinal region. (St. Louis City Hospital.)

of the bones obviously adds to the severity of any crushing injury. Treatment of such crushing injuries should be undertaken with extreme conservatism. Years ago, before the aseptic era, amputation was frequently necessary because of the likelihood of severe infection. The various aspects of crushed extremities as related to amputation are discussed in Chapter 13.

INFECTED WOUNDS

All open wounds sustained by accidents are contaminated; most of them will become infected unless treated adequately by methods already described in this chapter. Even the majority of wounds created in the operating room for elective procedures are contaminated by one or more of the various mechanisms described in Chapter 4; some of these are so badly contaminated that infection develops later after closure. In general the development of infection depends on three factors: (1) the amount of contamination, (2) the virulence of the organism, and (3) the resistance of the patient, i.e., as related to immunologic factors. A substance recently isolated from blood serum by Pillemer and associates (29) and given the name *properdin* promises to be a very potent factor in the resistance of the body to infection. It is a protein (euglobulin) comprising not more than 0.03 per cent of the total serum protein. The properdin system, consisting of properdin, complement, and magnesium has been identified as a natural defense mechanism of blood (Benson and associates, 30). "It kills certain bacteria, neutralizes some viruses, and lyses certain abnormal erythrocytes"; it functions without a specific antibody. Benson and associates report further that a depression in the properdin level is noted in pulmonary complications, paralytic ileus, peritonitis, gastrointestinal bleeding, and surface wound infections but does not persist beyond the duration of the disease process. No changes were noted following anesthesia, operative or accidental trauma, removal of the adrenal glands, or removal of the spleen. More study of this substance will be required to determine how

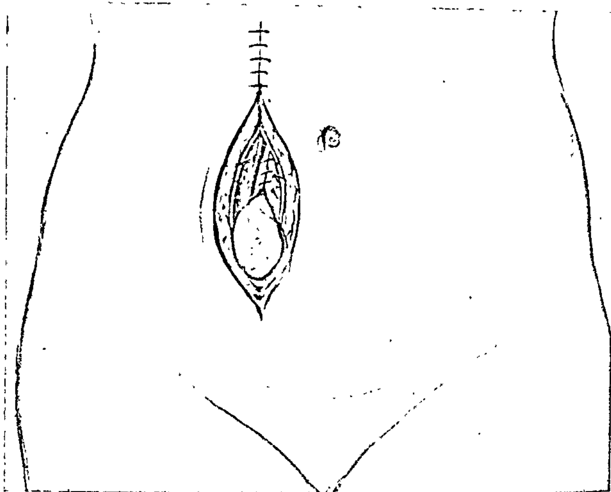


Fig. 19. Dehiscence of abdominal wound. This patient, age 65, had a carcinoma of the pancreas and had been jaundiced for six weeks. Because the tumor was advanced, only a cholecystojejunostomy was done. The patient developed postoperative atelectasis with persistent coughing. On the eighth day the dressing suddenly became stained with serous fluid; inspection of the wound revealed a small loop of ileum protruding. Closure with through-and-through silk sutures was carried out.

Rarely is the defect large enough to demand skin graft. A variable amount of swelling, produced by edema and hemorrhage, develops shortly after the injury. Such injuries are usually very painful. A surprisingly large amount of disability (fingers and hands) is associated with the injury. Not infrequently, there will be sufficient scar deposited in or about the muscles and tendons to produce a permanent contracture. Prompt incision of the fascia overlying the damaged muscle will prevent contracture if swelling is marked.

Occasionally, crushing injuries of the extremities as sustained in railroad accidents, for example, may be of sufficient magnitude to demand amputation. Laceration and tearing of the skin and deep tissue usually exist. Large vessels may be torn, resulting in severe hemorrhage which may be internal or external, depending upon whether or not the skin is broken. Crush injuries are often accompanied by severe shock which is not always helped by transfusions of blood or plasma. Formerly it was assumed that the loss of serum and blood was the major factor in the production of shock. At present considerable evidence has been adduced that a special entity called *crush syndrome* may follow crushing injury. A toxin, presumably of bacterial origin, is produced in the crushed muscle; when this toxin is absorbed, it gives rise to serious manifestations of shock and to renal damage later. The extravasation of fluid, and hemorrhage from smaller vessels may be sufficient to compress the larger vessels and produce gangrene per se. Fracture

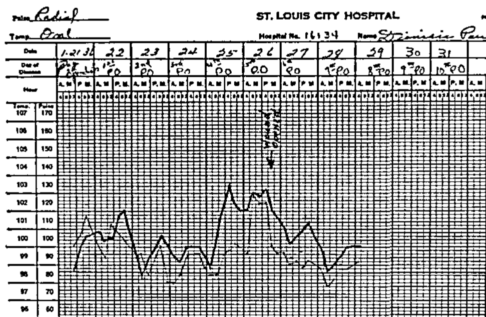


Chart 1. Postoperative wound infection in a 25-year-old man following a herniotomy. Note the fall in temperature following the opening of the wound. The organisms cultured from the pus were streptococci and staphylococci. The infection was traced to a respiratory infection in one of the operating room personnel. Recovery was uneventful.

from slipping into the depth of the wound. If the entire wound is infected and the symptoms are fulminating, it will be advisable to remove all the sutures and open the wound in its entire extent for adequate drainage. Such radical treatment is frequently necessary when the causative organism is a virulent streptococcus. On most occasions, drainage, as mentioned above, may be instituted without an anesthetic simply by separating the wound edges. Counter incisions of course require an anesthetic, local or general.

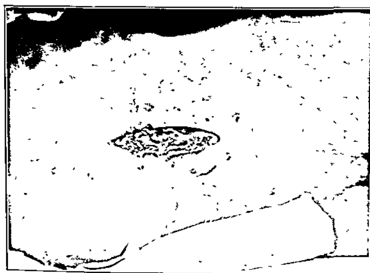


Fig. 21. Postoperative wound infection. A few days after laparotomy the entire wound became swollen, reddened, and tender and was therefore opened for drainage by removal of all skin sutures. Healing is now (two weeks after operation) taking place by the process of granulation.

this information can be utilized in the treatment of infection.

Mucoproteins appear to aid the body in its fight against infection or to increase the efficiency of antibiotics. For example, Howes and Armitage (31) noted that when 0.1 per cent mucoproteins were combined with antibiotics in the treatment of experimental wounds four hours after infliction, the development of infection was only 10 per cent as compared to 50 per cent infection if antibiotics were used alone.

The mechanisms of contamination in infected wounds have already been discussed but are summarized briefly here. In accidental wounds, contamination at the time of injury is obvious. In wounds made in the operating room, contamination takes place most commonly from the mouth of the personnel. Coughing, sneezing, and forceful breathing will force air through the average mask so suddenly that filtration of the air by the mask is ineffective. Contamination of gloves by touching nonsterile objects is common with inexperienced personnel. Less commonly, faulty sterilization may be the cause of contamination. The air in the operating room always contains a certain number of bacteria; the actual number of bacteria is related to the ventilation and number of people working in the operating room. The danger of infection of wounds in the operating room through inadequate ventilation of the operating room has been emphasized by Shooter and associates (32).

Clinical Manifestations. The classical manifestations of wound infection are redness, pain, tenderness, swelling, and local heat. In addition an induration is present at the site of infection. Fever develops relatively early in all acute infections. On some occasions, lymphangitis evidenced by a red streak leading from the wound (or a point nearby) will be present. Lymphadenopathy involving the nodes to which the wound is draining is present in practically all patients with wound infection. Leukocytosis is common. In the late stage of infection when pus accumulates, fluctuation will be present unless the infection is deep. Numerous systemic manifestations including headache, malaise, anorexia, weakness, and backache, may be present. With streptococcus infections, the above manifestations may develop in 24 to 48 hours; in staphylococcus infections, the manifestations develop more slowly, at times not becoming prominent for four to six days. Other organisms commonly found in wounds by culture are *Escherichia coli, Proteus vulgaris*, and *Pseudomonas aeruginosa* (*Bacillus pyocyaneus*). Detailed enumeration and description of organisms producing wound infection may be found in Chapter 6.

As the infection progresses, granulation tissue develops as a mechanism of protection and healing. It is moderately impervious to penetration by bacteria, and, if a layer of granulation tissue develops around the infected area, the infection with its accompanying manifestations will be limited, to some extent at least.

Treatment. The *importance of rest* of the affected part in the treatment of infected wounds should again be emphasized. If the wound is on an upper extremity, a sling may furnish sufficient immobilization; if on a lower extremity, bed rest may be required. Treatment varies considerably, depending upon the type and severity of infection. In the absence of suppuration, drainage is unnecessary, but, if there is any question about the presence of pus, a blunt instrument may safely be inserted between the edges of the wound under sterile precautions to determine whether or not pus is present. If a few drops of turbid fluid or pus are found, the insertion of a small rubber drain will do no harm and may prevent spreading of infection into the adjacent tissue. When a wound becomes infected (though not requiring removal of skin sutures), the sutures must be left in longer than the regulation time of five or six days because of the delayed healing and consequent danger of separation of the wound edges.

If an abscess develops in the wound, it should of course be opened as soon as detected (Chart 1). Two or three sutures may be removed, the wound spread, and the pus evacuated (Fig. 21). If the cavity is not large, such an opening should be adequate, especially if a rubber dam drain is inserted. As mentioned previously, such drains must be anchored in some way to prevent them

cated. However, because of the development of resistant organisms by chemotherapy, there is a growing tendency to use prophylactic therapy less and less. It should be emphasized that prophylactic antibiotic therapy must not be given to patients having such uncontaminated wounds as herniorrhaphy, appendectomy for unperforated appendicitis, and cholecystectomy.

When incision into the intestinal tract is contemplated—as, for example, colectomy for carcinoma—considerable contamination of the peritoneal cavity and wound may take place. Accordingly, the use of antibiotics to reduce the number of bacteria in the lumen of the intestine is justifiable, although a few surgeons may not agree. If intestinal antisepsis is sought, neomycin is about the most effective agent. It is often combined with oxytetracycline (Terramycin) or bacitracin. The latter agent is particularly effective against streptococci and clostridia, whereas neomycin is particularly effective against *Escherichia coli* and proteus; accordingly these agents act in a synergistic manner. Neither is absorbed from the intestinal tract; systemic reactions are therefore extremely uncommon. Some surgeons are of the opinion that Sulfathalidine is less apt to result in development of resistant strains of bacteria.

When antibiotics are given for *treatment of active infection* the offending organism should be identified. Accordingly, a culture should be obtained as soon as the infection is discovered, but a broad-spectrum antibiotic should be given until sensitivity tests on the organism are completed. The sensitivity tests should be conducted on five or six important antibiotics, such as penicillin, streptomycin, tetracyclin, chloramphenicol (chloromycetin), and erythromycin. If the organism is resistant to these, it should be tested with still other antibiotics. Although penicillin is very effective against the streptococci, numerous strains of staphylococci are becoming resistant to it. In general, there is not a very significant tendency for organisms to become resistant to chloramphenicol and erythromycin; accordingly, these antibiotics are becoming quite useful in the treatment of active infection. Erythromycin is particularly effective against most of the stains of staphylococci which are resistant to penicillin; it is not very effective against gram-negative organisms. Polymyxin is perhaps more effective against the pseudomonas (pyocyaneus) organisms than any of the other agents in use at the present time; however, nephrotoxicity is occasionally encountered with systemic use of this agent.

Some antibiotics act synergistically whereas others are antagonistic. For example, Jawetz (34) has found that synergism often exists between two of the bactericidal group (penicillin, streptomycin, polymyxin, neomycin, and bacitracin) and between the bacteriostatic group (chlortetracycline, oxytetracycline, and chloramphenicol). However, he noted that antagonism often develops when one of the former group is given with one of the latter. Details of chemotherapy may be found in Chapter 5.

Although the antibiotic and chemotherapeutic agents discussed above are very effective in the treatment of infections, the sulfonamides must not be forgotten. Often they are effective when used with one of the agents just discussed, or they may even be effective when used alone (see also Chapter 5).

In *summarizing* the treatment of infected wounds, the importance of obtaining early and adequate drainage of the wound should be emphasized. If the infection is mild, a simple separation of the wound edges with the insertion of a small rubber drain may be sufficient. If an abscess cavity has formed, the wound must be opened adequately, and, if necessary, counter incisions may be made so that there are no undrained undermining pockets. Rest of the affected part is extremely important in preventing the invasion of new tissue by infection. Cleansing of the infected wound by daily dressings is known from experience to encourage healthy granulations and healing; however, unless proper aseptic technic and gentleness are maintained during change of dressings, more harm than good may result. Aseptic technic in dressing is, of course, essential in order to prevent secondary infection, especially during the time before a wall of granulation tissue has formed in the wound (five to six days). Antibiotics are very effective in the

Except in mild infections, hot wet dressings are beneficial and usually advisable for 24 to 48 hours. If the wound is extensive and considerable necrosis of tissue is present, Carrel tubes may be inserted and the wound irrigated with a solution of penicillin (250 to 500 units per ml.). After the infection has subsided and the cavity has been obliterated, the edges of the wound, if small, may be approximated by means of adhesive; it may be advisable to do a secondary suture.

If the wound is large, *secondary closure* will be indicated to shorten the period of convalescence and repair. Areas of granulation tissue no wider than 1 or 2 cm. will be covered fairly satisfactorily by epithelial regeneration. If epithelium is allowed to cover areas wider than this, it will be thin and covering a dense layer of scar; thus, it will not be very resistant to the irritation to which skin is normally subjected. Epithelium will not grow down into a cavity; the cavity must first be filled with granulation tissue. If the granulating wound is wider than 2 or 3 cm., secondary closure or skin graft to the area will be indicated. Secondary closure cannot be done successfully until all necrotic tissue has separated and the granulation tissue has a pink healthy color. Closure can be accomplished more successfully if it is done before the depression at the site of wound separation has filled in. At times it may be necessary to undermine the skin and subcutaneous tissue to obtain good approximation, but this is undesirable because the protective layer of granulation tissue is thus broken and bacteria from the granulating surface are allowed to invade the fresh tissue opened by the undercutting incisions. In the average infected wound, secondary closure must be delayed 6 to 12 days after the incision has been opened to drain the infection. However, when fresh wounds are left open because of severe contamination during accidental infliction, secondary closure may at times be carried out successfully in two or three days. Such wounds should be packed with dry gauze, and heavy chemotherapy should be instituted to prepare them for such early closure. Local application of the enzymes streptokinase and streptodornase, as introduced by Tillett and associates (33), may be helpful in shortening the period of preparation of the wound.

Dressings on infected wounds should be changed every day to prevent pooling of the purulent exudate. Dressings should consist of dry gauze or wet dressings. As the granulation tissue develops, it is usually desirable to cover the wound with a strip of fine mesh gauze which will prevent granulation tissue from growing through the interstices of the gauze.

Skin grafts can be applied when all necrotic tissue has disappeared and the granulation tissue has a healthy pink color. It is usually desirable to wait until the depression created by separation of the wound edges has filled in with granulation tissue. Since full-thickness grafts will not take on granulation tissue, Thiersch grafts are the grafts of choice; they are superior to pinch grafts because final healing is slower after application of pinch grafts.

Chemotherapy in the treatment of wounds may be prophylactic or given for active infection. Each is important, but the principles utilized in the two methods are quite different.

Prophylactic chemotherapy is designed to prevent development of infection following contamination. It must be realized that all accidental wounds are contaminated; so also are abdominal wounds in operations during which the intestinal tract is entered. Under these circumstances the indications for chemotherapy are by no means clear-cut. In accidental wounds, prophylactic therapy will not be indicated if the wound is relatively clean, particularly if treatment is carried out within a few hours following injury; however, it will be indicated in all patients with grossly contaminated wounds. Since the contaminating organisms in accidental wounds are extremely variable, it is desirable to give an antibiotic or combination of antibiotics havings a wide spectrum of activity. A combination of penicillin (1,000,000 units per day) and streptomycin (2 gm. per day) meets this need about as effectively as any other agent or agents. This treatment should be continued for five or six days. In patients having operations on the intestinal tract, the same antibiotic therapy may be indi-

section except when sharp dissection becomes dangerous. Scissors may be used for blunt dissection but should not be used to cut tissues. Artery forceps should be placed on the bleeding point, avoiding large bites. Retraction must be gentle, and other precautions must be taken, as previously described in this chapter. A few years ago when the diathermy or electrosurgical knife was introduced, it was thought that less trauma would be inflicted on the wound because very few ligatures were required. However, even the slight charring of the skin induced by the electric knife resulted in damage to tissue which, as was shown by Ellis (35), delayed healing to such an extent that primary healing was obtained in only 60 per cent of instances versus 97 per cent following incision by a sharp scalpel.

4. **Lack of Immobility.** Lack of rest for the effected part is very detrimental to healing and, in the case of freshly closed wounds, may result in infection or hemorrhage. Perhaps more frequently, however, it delays healing by breaking down the newly regenerated tissue, which is very friable and nonresistant to stresses when only a day or two old. Even though rapid healing calls for immobility of the injured part, the patient himself should be ambulated unless contraindicated for reasons discussed elsewhere.

5. **Mechanical and Chemical Trauma.** The constant irritation by portions of clothing or appliances likewise interferes with healing to the extent that removal of sutures in the routine time (five to six days) may allow the wound edges to fall apart, even though infection is absent or not demonstrable. Obviously, any severe trauma, such as a blow inflicted over the wound, may destroy the repair which has taken place since the injury by disrupting the adhesion of the edges and sides of the wound. The application of ointments containing irritating chemicals (particularly phenol) will also interfere with healing. One of the most frequent causes of delayed healing of an abdominal wound, even to the point of actual rupture, is the development of a persistent cough during the first days of convalescence. Active measures must be undertaken to eradicate cough, retching, vomiting, hiccups, and excessive movements of the patient to prevent delayed healing. However, tight abdominal binders are undesirable because they interfere with respiration and may produce pulmonary complications.

6. **Foreign Body.** Any wound tolerates the presence of a foreign body poorly. Although certain objects (e.g., Lane plates, braided silk sutures, and other coarse fixative material) sometimes remain innocuous in aseptic wounds, they should be used only when necessary because of the tendency to convert a minimal contamination into a severe infection with the development of a *persistent sinus* (Fig. 23). Obviously, the more "dirt" that is imbedded with the foreign body, the more likely is the possibility of development of infection. On the other hand, a clean object, such as a piece of glass from a broken tumbler, may be buried in a wound, which

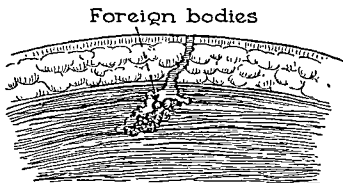


Fig. 23. Infection and sinus formation resulting from retained foreign body in the wound. The wound was carelessly closed without proper débridement and removal of foreign bodies, which are still embedded in the subcutaneous tissue. Healing is impaired, in fact prevented, by the foreign bodies and consequent suppuration.

invasive stage of infections, particularly those produced by the coccus organisms. However, they are not a substitute for incision and drainage of an abscess.

CAUSES OF DELAYED HEALING

1. **Infection.** Of the many instigating factors, the most important cause of delayed union, at least from the standpoint of frequency, is infection. In the presence of infection the incised tissues of the wound fail to adhere to each other and pus accumulates between them. This failure of union is usually more marked in the subcutaneous tissue than in the skin itself. The presence of an infection in a wound, even though it is adequately drained, may delay solid healing with complete closure from the average time of about 10 days to several weeks.

Occasionally a chronic infection, such as blastomycosis, actinomycosis, tularemia, and tuberculosis, is implanted into the wound at the time of injury and results in the formation of a chronic ulcer or sinus. The various peculiarities of these infections should lead to a correct diagnosis. Although many such infections are very resistant to treatment, they are fortunately not common.

Practically all the conditions listed below as factors in the causation of delayed healing are, likewise, important because of the tendency to encourage the development of infection. In many instances a wound becoming infected and healing by secondary intention would have healed per primam if that factor had been eradicated.

2. **Incorrect Closure.** If the subcutaneous tissue of the wound is closed inadequately so that a dead space is formed, fluid will accumulate within it and will remain for many days before it is absorbed and the cavity is filled with granulation tissue. If the skin edges are overlapped during approximation, they will separate and expose subcutaneous tissue when the sutures are removed (Fig. 14).

Not infrequently a hematoma will form within the depth of the wound because of failure to ligate all bleeding points at time of closure of the wound. Occasionally, a vessel which is cut or torn at the time of injury is not bleeding during closure of the wound, but the clot in its lumen becomes dislodged, and hemorrhage ensues after closure. This is prone to occur when a low blood pressure develops during the operation and returns to normal after closure of the wound.

3. **Excessive Trauma During Operation.** As stated previously, careful surgical technic aids asepsis. Careless technic, including rough handling of tissue and excessive trauma, results in delayed healing, not only because of the increased tendency to infection, but also because of the excessive amount of necrotic tissue produced (see Fig. 22).

Incisions should be made with a sharp scalpel, which should likewise be used in dis-

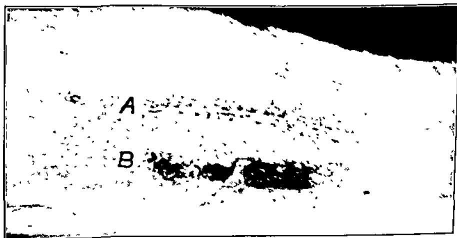


Fig. 22. Photograph illustrating the value of careful operative technic. Both incisions were made on the animal's abdomen seven days previously. Wound A was made and closed with careful technic whereas in wound B the tissues were handled roughly, with crushing of tissue, and so forth.

of rats, at least the ones guilty of attacking the sleeping human being, are infected with the spirochete (*Spirillum minus*) which is responsible for rat-bite fever (see Ch. 7).

Snake bites are dreaded, perhaps, more than the bites of any other animal, but fortunately, of the various kinds of snakes found in North America, only four are poisonous. The rattlesnake, copperhead, cottonmouth moccasin, and coral snake comprise this group. At the present time, several reputable pharmaceutical companies make an antivenene which contains antitoxin for the toxin contained in the venom of the first three snakes mentioned above and, if given in time (up to 8 or 10 hours) and in large quantities, may prevent a fatal outcome. Unfortunately, antivenene is rarely available at the time of injury, and it is necessary to resort to other measures while this is being procured. If the bite is inflicted by one of the four snakes mentioned above and on an extremity, it is advisable to apply a tourniquet which is tight enough to obstruct the lymphatics—part of the venous flow—but which *must not* block the arterial supply. Cross incisions are then made with a sharp knife through the fang marks. Suction is very effective in draining toxin out of the incised area, providing the incisions have been made adequately. The best method to apply suction is to use a regular cupping apparatus; if not available, one may be made by taking a large rubber bulb and inserting the end of a small funnel into the open end of the bulb. In absence of such apparatus, suction may be achieved by the mouth although the resultant infection is a serious disadvantage. There need be no fear of being poisoned by the absorption of venom through the mouth or intestinal tract, since the venom is destroyed by the digestive ferments. Absolute rest of the patient is essential. One of the most serious mistakes that can be made is to give the patient large doses of alcohol, since the depressant effect of the alcohol accentuates the depressant effect of the venom on the medullary centers and thereby hastens death. The seriousness of snake bites is considerably exaggerated since not over 15 to 18 per cent of untreated rattlesnake bites in adults are fatal. The bite of the cobra, encountered in the Eastern Hemisphere, is by far the most fatal of all snake bites. About 40 per cent of

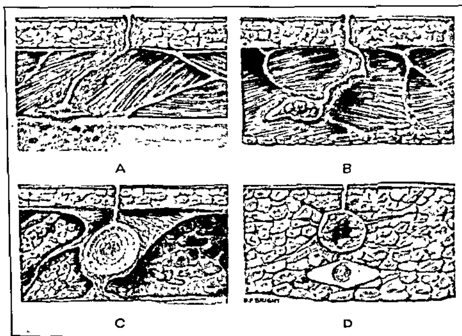


Fig. 24. Types of sinuses. A, sinus maintained by a foreign body (sequestrum); B, insufficient drainage of an abscess retards healing and may encourage spread of the infection; C, sinus communicating with a tuberculous lymph node; D, sinus connected with a pilonidal (epithelial lined) cyst which tends to become infected even before primary rupture of the sinus; strictly, this is a fistula.

will heal without the subsequent production of any difficulty except pain and local tenderness over the object. Some foreign bodies which are supposedly inert may interfere considerably with healing even though present in small quantities. Talcum powder, which was used years ago to powder hands and gloves, is an example of such an irritant; the resultant tissue reaction may give rise to granulomas and scar formation. Corn starch preparations, specially treated to maintain lubricating qualities after autoclaving, appear to be satisfactory substitutes.

7. **Impaired Circulation.** An example of the deleterious effect of impaired circulation on the healing of a wound is encountered when a patient is allowed to walk around as usual with a wound on one of the lower extremities. This delayed healing may be manifested by a slight amount of redness and edema, due presumably to the inadequate circulation created by the dependent position. Removal of sutures under eight days in such instances may result in separation of the wound edges. The sluggish healing of wounds in the lower extremities of patients with varicose veins, arteriosclerosis, and other vascular diseases may be explained on the basis of impaired circulation. On rare occasions, bandages, casts, or splints may be applied so tightly as to prevent healing because of impaired circulation resulting therefrom.

8. **Malignancy.** A wound inflicted in malignant tissue will very seldom heal. This situation will rarely be encountered in wounds sustained in accidents but is a frequent cause of difficulties in the operative treatment of malignant disease. For example, if the anastomosis following the excision of a carcinoma of the intestine is performed through malignant tissue, there will very likely be a leak at that point because of lack of healing. Such a complication is, of course, very serious because it usually leads to general peritonitis.

9. **Malnutrition.** Wounds sustained by patients suffering from a severe grade of malnutrition and dehydration usually heal very slowly. Severe anemia may delay healing. More important in the proper healing of [illegible] protein nutrition, as emphasized years ago by Clark (10), and Howes (11), and others. Ano portant cause of delayed healing an disruption lies in a low vitamin C blo Proof of this relationship was first by Lanman and Ingalls (8), who sh animal experiments (guinea pigs) th the vitamin C content in the blood the scorbutic level, delayed heali wound disruption were common. T tionship of tissue and blood pro wound healing and various surgical cations has been discussed in detail din and Gimbel (12).

10. **Miscellaneous Causes of Healing.** There are numerous local which may be responsible for lack ing, especially when the wound is loc one of the lower extremities. On ra sions, delayed healing will be caused temic diseases such as syphilis and culosis.

WOUNDS INFLICTED BY ANIMALS AND INSECTS

Dogs and cats are responsible for the wounds inflicted by animals. The bility of contraction of rabies from th other animals is discussed in Cha Moreover, there is a strong possibility development of local pyogenic infecti cause of the myriads of pathogenic isms constantly present in the mou such animals and because of the pene nature of the wound made by the Wounds caused by the bite of a cat are more prone to become infected than caused by a dog, but neither are as li result in infection as a bite inflicted man teeth (see p. 350). If the wo superficial (e.g., a cat scratch) an within a few minutes following the i thorough cleansing with soap and wa the application of an antiseptic such as cent aqueous solution of iodine (U may be very helpful in preventing the opment of infection. A sterile dressing of course, serve as a protection and p secondary infection.

Rat bites are not uncommon and are commonly sustained at night while th tient is asleep. A surprisingly large nu

sess the qualities of permanency or chronicity. 3. There are several *chronic infections,* including especially tuberculosis and actinomycosis, which form sinuses resulting from the rupture or incision of abscesses which fail to heal. 4. A sinus is often due to the presence of *epithelial cells* lining the track. These cells secrete more or less constantly and prevent healing and closure of the sinus. A common example is the draining wound in the neck caused by a persistent thyroglossal duct. Another example is a pilonidal cyst which so commonly opens to the exterior and fails to heal.

Any *treatment* which aims to eliminate a sinus depends, of course, upon the etiologic factor. This must be determined if possible. Injection of the track with a radiopaque substance (iodized oil) followed by a roentgenogram often reveals the extent and relationships of the sinus. Examination by the roentgen ray will also aid in this differentiation if a radiopaque foreign body is present. Gentle probing of superficial sinuses occasionally reveals the presence of a foreign body. After removal of foreign bodies, sinuses usually close within a few days. A secreting epithelial lining must be completely removed by excision or destroyed by chemical cauterization, preferably the former. A preliminary injection of the sinus track with methylene blue will so visualize its ramifications as to make complete excision easier. If inadequate drainage is the cause of the sinus, a thorough incision should be performed. If tuberculosis or actinomycosis is the etiologic factor, local treatment will usually be facilitated if the entire local process can be removed.

FISTULA

A fistula is an abnormal communication between epithelial- or endothelial-lined surfaces (usually hollow viscera) or a communication between a viscus and the exterior. They may be produced in several different ways.

1. Occasionally the communication may

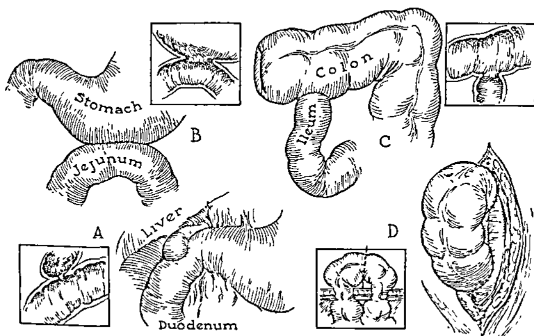


Fig. 26. Common types of intestinal fistula produced by operative means. A, cholecystoduodenostomy, performed usually for carcinoma of the pancreas or inoperable carcinoma of the ampulla of Vater; B, gastrojejunostomy, utilized in stenosis of the pylorus or duodenum; C, ileocolostomy, commonly performed in resection of the proximal colon for carcinoma; D, double-barreled colostomy, as performed to correct obstruction in inoperable carcinoma of the rectum, or in the Lockhart-Mummery type of resection of the rectum for carcinoma. On the second or third day the sigmoid is cut across, as shown by the dotted line in the insert.





Fig. 25. Sinus of groin. The patient was a four-year-old boy who stepped on a sharp object while playing; the wound healed (above), but two months later lymph nodes in the groin suppurated; after incision of this abscess, a sinus (below) developed and persisted for a year. Excision resulted in a cure. Microscopic section revealed chronic inflammation (not tuberculosis). Culture was negative. This chronicity is rather unusual, but chronic sinuses develop occasionally, particularly when the organism is microaerophilic.

people bitten by the cobra will die unless treatment is given instantly and adequately. ACTH and cortisone are quite effective in the treatment of snake bites. Hydrocortisone given intravenously will act more rapidly.

There are numerous insects whose bites are poisonous, but very few, indeed, are fatal. The most common of the poisonous bites are those inflicted by the black widow spider and the scorpion. The condition produced by the bite of poisonous spiders is called arachnoidism. The black widow spider is probably the most poisonous of all the members of the Arachnida class of insects. It is about 1 cm. in size and is recognized by a red area shaped like an hourglass on its abdomen. Important to the surgeon is the fact that the bite of a black widow spider may be soon followed by severe abdominal pain; examination may reveal a hard "boardlike" abdomen which simulates that observed in perforated peptic ulcer. There is, however, little associated tenderness, and, within a few hours, the signs and symptoms gradually disappear although distention may be present and persist for several days. The bite is associated with a fatality of less than 1 per cent (Kirby-Smith, 36).

SINUS

A sinus is a tract extending from the surface of the body into the deeper tissues, which frequently becomes the site of chronic discharge or suppuration. The superficial part of the lesion may appear to be a simple ulcer, but the history and examination will reveal its true nature. There are four main factors (Fig. 24) in the production of a sinus: 1. *Foreign bodies* such as metal, wood, unabsorbable sutures, necrotic bone (sequestrum), and fecaliths, in the presence of an infection, may lead to a sinus which may be permanent unless the foreign body is removed. 2. Perhaps the most common sinus encountered results from *insufficient drainage* of an ordinary pyogenic infection. The cause of the insufficient drainage may be inadequate incision of an abscess, tortuosity of the drainage tract, the presence of a collar-button abscess, lack of a dependent opening, or chronically infected lymph nodes (Fig. 25). When an ordinary abscess heals there is usually an interval of a few days when a discharging inflammatory tract is present after the walls of the cavity have approximated. Theoretically this should be called a sinus, but obviously it does not pos-

the patient does not first succumb to peritonitis caused by the leak in the suture line.

The *treatment* of fistula depends upon its location and cause. If the communication has followed some type of infectious process, excision of the fistulous track and closure of the opening in the viscus will usually effect a cure. A fistulous communication between two loops of intestine may be cured by dissection of the walls from each other, excision of inflammatory edges, and closure of the openings. Resection of the affected loops followed by an anastomosis may be necessary. The edges of the opening in the intestine must be inverted since union will occur only when the peritoneal surfaces are approximated. A fistula produced by malignant tumors cannot be cured by closure with sutures, but it may be eliminated if the growth can be completely excised and the resultant defect repaired with complete obliteration of dead space at the site of excision.

As already stated, most fecal fistulas, with the exception of those high in the intestinal tract, will heal spontaneously unless there is an obstruction distal to the fistula. If such an obstruction is present, it will obviously have to be corrected by operative means before the fistula will close. If the fistula persists because of attachment of the intestinal mucosa to the skin, an operation consisting of division of the union between mucosa and skin with inversion of the intestinal mucosa should result in a cure. Occasionally, such a repair will produce so much narrowing of the intestinal lumen that either obstruction or a recurrence of the fistula will result. On such occasions, resection of the defect, with an anastomosis between the two loops (proximal and distal) of intestine is indicated.

As will be noted in the above paragraph, the suffix "*ostomy*" is commonly utilized to signify a fistulous communication between different organs of the body (especially intraabdominal). The term implies the opening of an organ without closure and establishment of communication with another organ or the exterior. The suffix "*otomy*," however, implies the opening of the organ or viscus and closure without establishment of a fistulous tract. When the suffix "*ectomy*" is used in connection with an organ or tissue, excision of that organ or tissue is implied.

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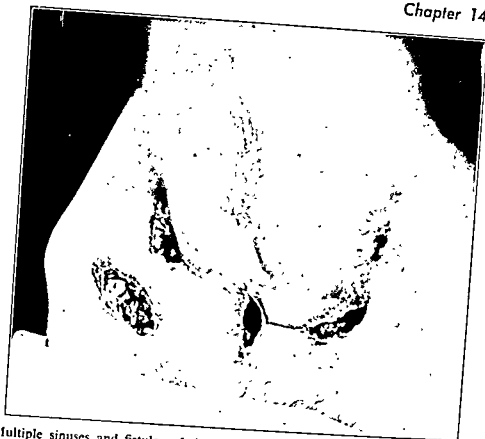


Fig. 27. Multiple sinuses and fistulas of the abdominal wall. Fecal material drains from c of the openings. The lesions are of three years' duration and followed a pelvic operation.

be *congenital*, that is, result from a defect in fetal development. Rectovaginal, rectovesical, and rectal fistulas are often associated with an imperforate anus.

2. *Postoperative fistulas* may be divided into two types. In the first group (*a*) the fistula is produced intentionally (Fig. 26), connecting one viscus with another for functional reasons, e.g., cholecystogastrostomy, ileocolostomy, gastroenterostomy. In a second group of cases (*b*) the fistula opens to the outside through accidental or intentional means, e.g., urinary fistula, biliary fistula. Pancreatic fistula and duodenal fistula likewise occur and develop most commonly following operations on the duodenum. A biliary fistula which persists is usually due to an obstruction distal to the opening. In a *fecal fistula* (Fig. 27) the intestinal content is diverted to the outside; it is frequently performed intentionally, e.g., colostomy, during a resection of a carcinoma of the rectum. When a fecal fistula results accidentally, it usually occurs because of a rupture of an intestinal suture line, which in most instances is caused by an obstruction distal to the

operative site. (Frequently, such : of intestinal contents produces a fata tonitis before a fecal fistula develops most occasions, fistulas which devel the absence of obstruction will close taneously; they may drain for months, ever. If the fistula is located high ii intestine, it will usually not heal spon ously; furthermore, it may result in th gestion of the skin or the walls of the wo

3. Fistulas caused by tissue destru due to severe *infection* are extremely c mon, as clearly illustrated by the rectal tula which forms as a complicating afterm of a rectal abscess.

4. Fistulas may be of *mechanical ori* A vesico-vaginal communication may deve as the result of pressure necrosis during chi birth. A cholecystenterostomy may be p formed by the passage of a gallstone from t gallbladder into the intestine.

5. Occasionally a *malignant tumor* m be responsible for the development of fistula. An intestinal operation performe through malignant tissue may produce a pe manent fecal fistula leading to the exterior i

15

THERMAL, CHEMICAL, AND ELECTRIC TRAUMA

A number of different kinds of trauma are considered in this chapter, all due to the effects of abnormal heat or cold, chemicals, electricity, and ionizing radiation. Abnormal cold causes freezing; high environment temperature causes heat stroke and heat exhaustion. The latter produce systemic effects but are not usually associated with any local lesion. Electric currents may burn or coagulate the skin and deeper tissues directly, may kill without obvious skin damage, or may cause flame burns by setting clothing on fire. Atomic explosions lead to burns and other systemic damage.

THERMAL BURNS

The skin and underlying structures may be burned by flames, by contact with hot water or other hot liquids, by hot metallic objects, by the sun, by contact with radiation from other hot bodies, by steam, by electricity, or by friction. Burns caused by hot liquids or steam are frequently called *scalds*. *Flash burns* are due to sudden exposure to the heated air of flame from an explosion, including that of an atomic bomb.

Pathology of Burns. Tissue changes caused by thermal injury vary with the duration and intensity of the exposure, and the particular part of the body involved. These tissue changes often lead to systemic effects which will be described under clinical manifestations.

Classification of the skin lesion in burns has always proved somewhat difficult and even now is sometimes confusing. This is due partly to an attempt to use too rigid criteria and partly to the fact that only with the passage of time can the true extent and depth of the necrosis be accurately estimated. In the following discussion, the extent (as measured by the depth and area of the burn) and the kind of damage will be used as the two primary groups for classification.

The Extent of the Burn. The local skin lesion may vary (*a*) as to depth, and (*b*) as to the area involved.

1. The *depth of the burn* is traditionally classified into first, second, and third degree. *In third-degree burns, the necrotic skin* which finally sloughs off extends through the entire derma (see Fig. 9 on p. 307). The first- and second-degree burns always heal spontaneously, whereas the third-degree burns, unless of a small area, always require a skin graft. An excellent study of this subject is that of Converse and Robb-Smith (1) who have classified the depth of burns into four types: 1. *epidermal,* in which erythema is followed by desquamation but without blistering; 2. *dermal,* in which blistering and superficial destruction of the derma is accompanied by edema into and under the skin, transudation into the blisters and through the bed of broken blisters, and hyperemia in the tissues under the burn; 3. *deep dermal,* in which there is destruction of

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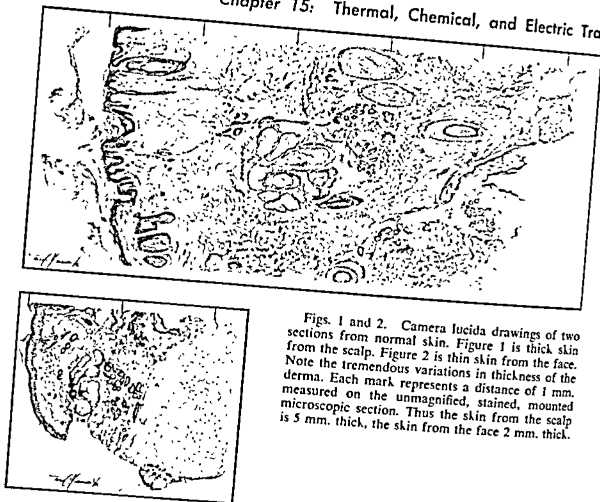
Fig. 3. Flash burn. Photograph taken on the tenth day following an explosion from a gasoline stove. Note the outline of the brassière which protected the underlying skin. The burned areas were practically all part thickness and complete healing can already be seen over the right side. The necrotic crust over other areas came away shortly afterward, leaving a healed base. The distal portion of the left upper arm was merely "tanned" without necrosis, as shown by the appearance of normal skin over a small area from which the superficial keratin layer could be readily removed.

Many of the burns following the atomic explosion in Hiroshima also showed the outline of clothing, indicating the protection offered from many flash burns by even light wearing apparel.

example, a fatal result may be expected in an extensive burn assumed to be all of third degree, whereas cure will follow because only a small portion was actually of third degree, as shown by the relatively small amount of skin grafting subsequently required. On the other hand, a less extensive and supposedly superficial burn may eventually prove fatal because it involved all thicknesses of the skin, as shown by sloughing later.

2. The *area of the burned skin* has an important influence upon the degree and severity of the systemic effects and especially on mortality. In general, serious reaction follows only in burns larger than 10 per cent of the surface area, the severity increasing directly with the percentage. However, the systemic effects also vary with the depth of the burn, its kind, and the age and general vigor of the patient. The aged, and very often children, are very much more vulnerable than young adults. The area of the burned skin is customarily expressed as a percentage of the total skin surface. This information, including an estimation of the depth of the burn, is essential not only for the care of the patient but for scientific study of burns in general. Helpful charts for measuring and recording the burned area in terms of percentage have been published by Lund and Browder (3) and are reproduced in Figure 4, which also shows the differences in various body areas at different ages.

The Kind of Damage. Entirely apart from depth and area, the thermal agent may produce either edema and swelling, or actual necrosis, or both. Moreover, the necrosis may be of the moist type or may be dry and hard. Moreover, these three kinds of tissue damage—edema, moist necrosis, and dry necrosis—may all be present in different parts of the same burn. In general, the necrosis tends to be moist in the periphery of the burn, hard and dry in its center. Exposure to very high temperature for a short time tends to cause a dry burn or eschar. Exposure to a lower temperature for a more prolonged time causes a necrosis with edema. Thus, flame burns are more apt to produce dry necrosis, hot-water and oil burns, moist necrosis. Such differences in the kind of skin damage are important not only in terms of eventual healing but particularly in the production of systemic manifestations, which are least apt to occur with dry necrosis and most apt to occur when there is considerable edema and/or moist necrosis. The latter is particularly likely to produce "toxic" manifestations due to the absorption of bacterial



Figs. 1 and 2. Camera lucida drawings of two sections from normal skin. Figure 1 is thick skin from the scalp. Figure 2 is thin skin from the face. Note the tremendous variations in thickness of the derma. Each mark represents a distance of 1 mm. measured on the unmagnified, stained, mounted microscopic section. Thus the skin from the scalp is 5 mm. thick, the skin from the face 2 mm. thick.

the deep layers of the derma, sparing the deepest epithelial elements such as hair follicles and the coils of sweat and sebaceous glands; 4. *deep,* in which the destruction of the derma includes all epithelial elements into and/or beyond clear fat of subcutaneous areolar tissue. Although a deep burn of this classification looks like a deep dermal burn, it is fundamentally different because spontaneous healing can occur in the latter, but not in the former, from remaining epithelial islands representing remaining portions of the hair follicles or sweat glands. *Mixed* burns, a separate group, are those in which small areas of deep dermal are interspersed with small areas of dermal burns.

It cannot be emphasized too strongly that an accurate estimation of the depth of the burn cannot always be made at the initial examination. Time must elapse until healing is well under way or, at least, until the overlying necrotic skin has been sloughed. Recent experimental studies on animals with radioactive phosphorus show that the depth of the burn may be estimated early, perhaps within hours of the accident (2). Some preliminary information may be gathered from the part of the body involved and the kind of thermal injury. As to the former, the thickness of the derma is important and differs widely in various parts of the body (Figs. 1 and 2). Moreover, the circulation of the blood also plays an important part by carrying away heat imposed by the thermal agent. For example, although the skin of the face is thin and presumably would be damaged more deeply by a given burn, the cooling effect of its excellent blood supply actually protects the tissues so that deep lesions are relatively uncommon in this part of the body. As to the kind of burn, a much deeper burn nearly always follows when the clothes catch fire than is true of a hot-water or a flash burn. If not ignited, clothing will usually protect against flash burns (Fig. 3).

Mistakes in prognosis are commonly due to erroneous estimates of the depth of the burn made at the initial examination. For

indicate "toxemia" as *shown by high fever,* increasing coma, irrational behavior, and irregular respirations. Later in the course of the burn, if severe infection supervenes, the *usual systemic manifestations* of suppuration will follow.

Anuria may occur after extensive burns. Even when uremia is not progressive the patient shows some depression of the sensorium, a diminution in the urinary output, and an increase in the nonprotein nitrogen of the blood. When occurring shortly after the burn, these manifestations may, however, be due to a decrease in blood volume and are often relieved by replacement therapy.

3. The *local lesions,* as already described, vary widely. *The history is of some value in that burns due to the actual flame, especially* when the clothes have caught fire, are nearly always deeper than scalds and produce a dry necrosis which (unless charred), on cursory *inspection,* may look like blanched skin. On palpation, however, such doubt is dispelled, for the coagulated tissue is insensitive and hard.

4. *Laboratory studies* should be started on admission and continued at frequent intervals until healing. A systematic approach is essential. On admission, a urine specimen is obtained and examined as routine with special reference to hemoglobinuria and cellular casts. Because knowledge of renal activity is essential (especially the prompt detection of oliguria or anuria), the severely burned patient should always be provided

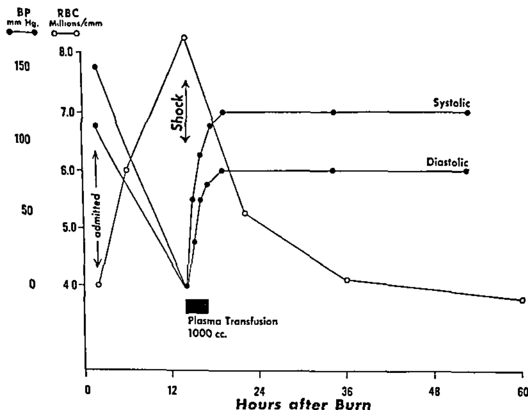


FIG. 5. Surgical shock and hemoconcentration in a severe burn. The patient, a seven-year-old boy, entered the hospital almost at once after sustaining a flame burn involving 30 per cent of the body surface. Note that on admission the red cell count was normal and that the blood pressure was slightly high. The patient's general condition was good and he took food and fluid well. Within 12 hours, however, typical shock developed with cold extremities, rapid pulse, and unmeasurable blood pressure. The red cell count increased synchronously. A rapid and large plasma transfusion (30 ml. per kg. of body weight) was followed by dramatic clinical improvement and, as shown in the chart, a prompt restoration of blood pressure and correction of hemoconcentration. Healing was eventually complete but required skin grafting. (From Elman, Merry, Beguesse, and Tisdale, Surg., Gynec. & Obst., 4.)

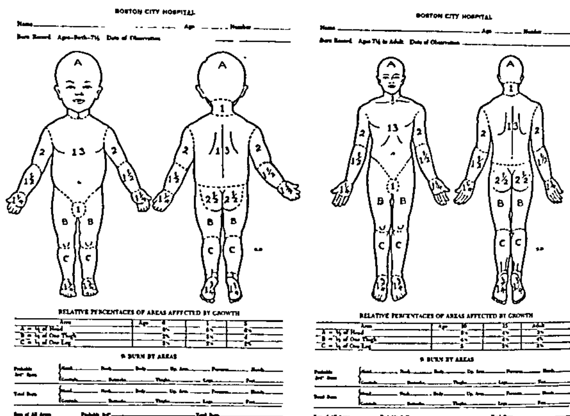


Fig. 4. Charts for measuring extent (area) of burn. Note that the area of the skin burned is expressed as a percentage of the total surface area. The numbers recorded are those of the feet, upper extremity, neck, and torso because these are the same at all ages. Note that the head, thighs, and legs (indicated by letters A, B, and C respectively) vary with age; during growth the surface of the head grows proportionately smaller, that of the thigh and leg larger. (From Lund, C. C., and Browder, N. C. Surg, Gynec. & Obst.)

toxins which have invaded. Thus, the kind of skin damage may greatly influence the likelihood of systemic disease.

Burns involving the respiratory tract are discussed later.

Clinical Manifestations. As might be expected, the clinical picture in a severe burn varies greatly due to the great variations in the extent and type of the local lesion, as well as in the age and general condition of the patient. The various manifestations are arbitrarily divided into the following five groups.

1. The *subjective symptoms* may be relatively few, even in severe burns. *Pain* is always intense at the time a flame or hot-water burn is sustained but usually disappears rapidly. Sunburn, however, is usually painful later and not initially. Ordinarily, the burned patient arriving at the hospital complains merely of discomfort, even though he may be apprehensive. Undoubtedly the memory of the intense pain plays an important part in these subjective manifestations. A second symptom of importance is intense *thirst*. Except when vomiting occurs, thirst is readily satisfied by drinking fluids which, however, should contain 0.5 to 0.8 per cent sodium chloride and bicarbonate. Pure water ingested in large amounts may lead to salt deficiency (water intoxication). Chilliness, even in warm weather, is a frequent complaint, but always disappears after the burned area is covered by the application of a dressing or is exposed to warm air.

2. The *systemic manifestations*, even with extensive burns, may be surprisingly few on admission to the hospital shortly after the burn is sustained. While the blood pressure may be reduced, it is frequently unchanged; the pulse may also be normal. The temperature, however, is often elevated. Within a few hours, however, particularly when there is extensive extravasation of fluid, the blood pressure may fall and the patient may exhibit all the signs of surgical shock. In other patients, the systemic manifestations seem to

weeks and months because of the poor general condition of the patient; yet, with the passage of time the general condition may deteriorate rather than improve. In many instances, this deterioration is based on extreme malnutrition due to a combination of anorexia and increased nitrogen loss from the excessive tissue protein destruction. These manifestations may be prevented to a great extent by special and early attention to nutritional intake as discussed under treatment.

Treatment. The fundamental principles of treatment are: 1. to lower initial mortality; 2. to avoid infection; and 3. to shorten disability and promote healing (4). Systemic therapy, because it is designed to lower mortality, rightly demands rigid priority.

1. *Systemic treatment* aims to combat shock and toxemia by replacing lost fluids and correcting other biochemical changes. Highest priority is given to restoring the blood volume to normal. Pain must be controlled when present, although most patients are free of it at the time they enter the hospital for treatment. The routine use of large doses of morphine is therefore unnecessary and indeed undesirable, because it depresses respirations, which is dangerous in the presence of pulmonary complications. If morphine is necessary, it should not be given subcutaneously or intramuscularly to patients in shock, but injected intravenously.

Prevention of deficits will undoubtedly reduce early mortality in most severe burns. The basis of this therapy is accurate replacement of losses which, especially when they occur in extensive edematous areas, consist essentially of physiologic saline solution plus some plasma protein and red cells. In addition, insensible losses of pure water are also increased, because of (*a*) fever and increased respiration, and (*b*) increased vapor loss through the burned rather than through the intact skin (Lieberman, 5). An important feature is to meet the needs of thirst, not by water alone, which may indeed reproduce signs of water intoxication, but by a dilute solution containing 0.4 per cent sodium chloride and 0.1 per cent bicarbonate. Most patients willingly drink this instead of water, especially if it is chilled.

Intravenous injections are not always necessary inasmuch as many burned patients will take an adequate amount of the right kind of fluids and food by mouth. However, in the presence of shock and hemoconcentration, especially in a patient who vomits, the intravenous channel must be used. In a carefully studied group. Markley and associates (6) found that 55 per cent of all patients with burns involving 10 per cent or more of the body surface were able to take all foods orally. About 40 per cent received fluids both orally and intravenously, and the rest by vein exclusively. However, up to 50 per cent of all patients had vomiting and/or diarrhea.

Intravenous infusions are indicated when blood or plasma is needed. The type of intravenous fluids to be given has aroused some dispute, but the best guide is a knowledge of the kind of fluid lost, so that true replacement therapy can be practiced. It is likely that the proponents of saline on the one hand and plasma or blood on the other are both correct in that the fluid lost in burns is a protein-containing extracellular fluid. Thus, the proper replacement would consist of physiologic saline, plus plasma and blood, the amount of each dependent upon the amount of insensible water loss, the extent of inflammatory edema, the degree of hemoconcentration, and the urgency of restoration of blood volume as shown by the signs of shock. Additional guides are the clinical response to therapy, the restoration of urinary output, and the estimates of fluid balance. Such a therapeutic approach actually is simpler and more likely to meet individual needs than is a strict adherence to rigid formulas. Rarely with pulmonary edema following respiratory tract burns (see p. 309) intravenous treatment may be contraindicated.

The principles expressed by Evans (7) may serve as guides to replacement therapy. For example, he has stated that if the burn includes more than 25 per cent of the body surface, about as much blood should be given as whole blood plasma or plasma substitute. For the first 24-hour period he suggests plasma, plasma substitute, or blood in quantities equal to 1 ml. per kilogram times the percentage of body surface burned; an equal

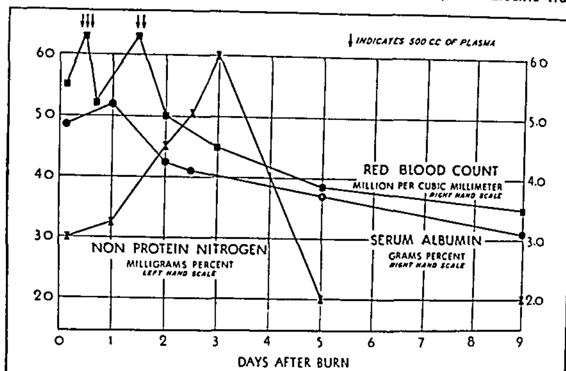


Fig. 6. Blood changes in a severe burn. The patient was a 45-year-old female whose clothes caught fire; she sustained a third-degree burn on about 40 per cent of the body. Note the complete correction of hemoconcentration following transfusion of 2,500 ml. of plasma and the fall below normal, in spite of this, of the serum albumin. Note also the rise and fall of the nonprotein nitrogen.

with an indwelling catheter in the bladder and all urine collected, measured, and examined. The red count and hematocrit or hemoglobin determination are of special importance because they show the onset and progress of hemoconcentration and thus give an indirect measure of decreases in blood volume (Fig. 5). Red cell counts as high as eight million per cubic millimeter have been found in severe cases. One or more of these examinations should be done every six hours for two days and at frequent intervals thereafter. The white cell count will nearly always show a leukocytosis, usually up to twenty thousand or more. The eosinophils disappear rapidly within a few hours, a manifestation of the so-called "stress reaction."

Blood chemical measurements include the nonprotein nitrogen content and serum and fractional proteins (Fig. 6). Acidosis, as shown by a low carbon dioxide combining power of the plasma, is not infrequent, particularly in severe burns. Such a finding represents an important feature of the systemic manifestations. A low plasma sodium either is due to the ingestion of pure water or is a part of the presumed change in cell permeability secondary to stress. With oliguria and anuria, the usual changes of renal insufficiency are found. Hypoproteinemia is apt to occur after several days and to progress if the nutritional intake is inadequate. Although hemoconcentration is frequent within 12 hours, anemia may occur after a few days and sometimes may be pronounced. Anemia is probably due to an actual destruction of red cells, to hemolysis, or to a depression in the normal hemopoietic function of the bone marrow.

5. *Later manifestations* are serious, but fortunately occur only in fairly extensive full-thickness burns in which there is a complete loss of skin. To a certain extent, many of these later manifestations are due to extensive suppuration, and the clinical manifestations are similar to those produced by infection from any other cause. Sooner or later, however, with adequate local treatment, necrotic tissue separates and the patient is prepared for skin grafting.

Too often, skin grafting is delayed for

patient and the surgeon, and enables constant inspection of the wound for changes, but does require meticulous care that the surrounding air is clean and contamination is eliminated. It is not suitable for burns that encircle the body.

The standard local treatment consists of the application of a comfortable, firm dressing (Fig. 7), with or without petrolatum fine-mesh gauze as an inner layer. Antibiotics and other chemicals should not be incorporated in this local therapy. Before the burned area is dressed, the wound may or may not be washed or treated. General washing or débridement may be used, but must be carried out gently without anesthesia and, of course, with strict aseptic precaution.

The application of the dressing involves certain principles. The inside layer consists of lengthwise strips, *never* of a circular bandage. Over this, multiple layers of gauze are placed to absorb discharge. A layer of cotton waste under the final outside circular bandage provides elastic pressure.

Most important in the application of the dressing over the burned area is covering the skin well beyond the obviously involved surface in order to be sure that no injured skin will be left exposed to become a portal of entry for infection. The edge of the dressing must also be firmly applied to the skin lest the patient introduce contamination with his fingers. Infrequent dressing is an important principle which will minimize danger of secondary contamination, the possibility of which is increased each time any large, open wound is exposed in an ordinary atmosphere for any length of time. When the open-air treatment is used, such contamination is prevented by isolation, cleanliness, and especially by keeping the exposed surface dry. Once an efficient dressing is applied, it should not be changed for a week or more except when definitely indicated by pain, excessive discharge, or serious infection. The policy of infrequent dressing should be explained to the patient at the outset of treatment lest he mistake it for neglect.

3. *Chemotherapy* plays only a prophylactic role in the treatment of fresh burns. Penicillin and streptomycin in full doses should be given by injection from the very start and continued for at least a week. After the first week, antibiotics should be used when indicated for the control of sensitive organisms and with due regard for the danger of causing diarrhea or other complications if given for too long a time or in too large doses. For a discussion of the indications, hazards, and limitations of chemotherapy see Chapter 5.

4. *Nutritional care* is frequently neglected, as it often is in surgical and other diseases of long duration (Fig. 8). This aspect

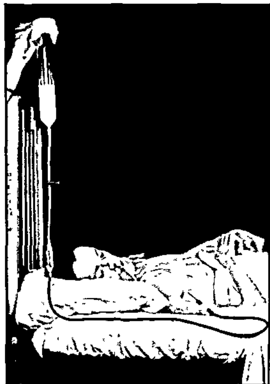


Fig. 8. Malnutrition in a neglected burn. The patient was a 17-year-old boy who was burned a year before. Note the evidence of extreme loss of weight, which had fallen from 150 to 70 pounds. Not shown are the extensive full-thickness burns involving both lower extremities, associated with considerable edema. Note also the arrangement for tube feeding with a tiny plastic catheter which was well tolerated and quite necessary in order to provide an adequate food intake in the face of extreme anorexia. He was also given a total of six injections (3 liters) of whole blood over the course of seven days. The red cell count and hemoglobin concentration, normal on admission, fell after the first two transfusions and then returned to normal. Donor skin from a recently deceased cadaver was then used as a temporary covering. It took and remained in place for several weeks. Later his own skin was transplanted and the patient eventually made an excellent recovery.

amount of physiologic saline plus 2,000 ml. of 5 per cent glucose (for an adult) should also be given. For the second 24-hour period he suggests giving half as much plasma or blood and electrolytes with the same amount (2,000 ml.) of 5 per cent glucose in water. He warns that no more than 4,000 ml. of colloid or 4,000 ml. of saline should be given in a 24-hour period, regardless of the extent of the burn. Evans emphasized that the formula is only a guide to therapy and not an infallible rule. The adequacy of treatment is confirmed by sufficient (25 to 50 ml. per hour) urine output and frequent determinations of the hematocrit or hemoglobin.

2. *Immediate local treatment* in small, first-degree burns consists merely of the application of a comfortable dressing for the protection of the burn after the area has been gently cleansed with warm water and soap. First aid in extensive burns consists merely of sedation when necessary, plus protection of the burn area with sterile dressings and immediate transportation to a site where definitive treatment can be carried out.

The local treatment of burned skin has undergone considerable change in the past one or two decades. In severe burns, scrupulous maintenance of aseptic technic is essential. The mouths of the patient and the personnel must be protected with masks so as to avoid droplet contamination. All steps in the care of the wound should be carried out with the same meticulous care as is used in the performance of a sterile surgical operation. Related to this factor is the importance of infrequent dressings of burns, inasmuch as each time the extensive area is exposed, the likelihood of further contamination is increased.

All forms of local therapy in burns except simple dressings and the open-air treatment (8) should now be considered out-of-date or experimental. The open-air method, without dressing, is certainly the simplest for the

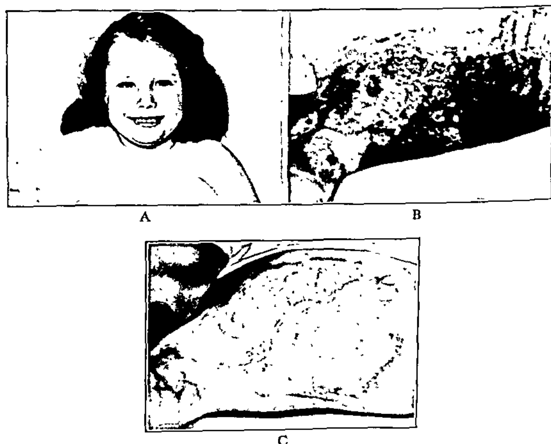


Fig. 7. A, child with third-degree burn of chest treated locally with dry gauze pressure dressings. Fourteenth day. Note obvious comfort. B, appearance of burn on fifteenth day. Note sloughing well advanced and granulations present. C, two months after injury. Burn grafted and healed. (From Cole, W. H. Operative Technic in General Surgery, Appleton-Century-Crofts, 2nd ed.)

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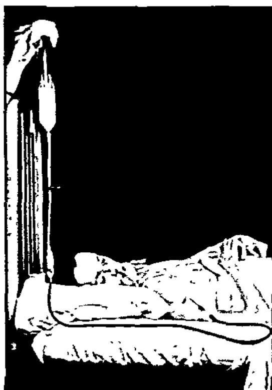


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;ical therapy is of decisive importance, ılarly in the extensive burns which re- ;kin grafting (9). Anemia, hypoalbu- ıia, loss of weight, vitamin and hor- deficiencies, all of which develop rap- 'ter severe burns and lead to delayed ; or to fatal complications, are still :valent. Yet they can be prevented, to : extent, by prompt attention to the nu- al needs of the burned patient. During ıte phase, deficits as already discussed be and usually are corrected. Just as :ant, often more so, is the provision of d food intake by mouth, beginning Only rarely will intravenous alimenta- f glucose, amino acids, and vitamins :essary. The diet must be as high in ı as possible, must be easily digestible, ust be easy for the patient to take and :rse to measure. Because of anorexia, ual try is generally inadequate. Much useful are concentrated drinks made :k, skimmed milk powder, or other 'es which, during the critical period, ıtient will swallow despite anorexia. nitial intake may have to be low, per- ·nly 1,000 calories per day, lest gastro- nal disturbances follow. But it must l balanced and contain at least 50 to m. of protein. As soon as possible a intake is reached, which may have to her than normal to correct inevitable ; that have developed during the acute

ɔe feeding may be indicated, especially lected late cases (Fig. 8). In addition ıdequate intake of calories and protein, s evidence that, in burns, large amounts tain vitamins are necessary, owing to ct that they seem to be either utilized, yed, or excreted at abnormally in- d rates, particularly during the active of the burn. Thus, during the first approximately the following amounts ven daily either by mouth or by injec- ıscorbic acid, 1 gm.; thiamine, 20 mg.; ıvin, 20 mg.; niacin, 200 mg.; pyridox- 0 mg.; calcium pantothenate, 100 mg.; ıcid, 25 mg.; and vitamin B_{12}, 25 mg.

Early skin grafting of defects produced rd-degree burns is an important feature in order to restore the patient to full activity as soon as possible, and thus to avoid the evils of a long convalescence. Skin grafting is required whenever nature's spontaneous efforts are faulty, particularly in large defects. Natural healing of lost derma involves replacement by scar, which contains no elastic fibers and no sebaceous or sweat glands and is covered by thin epithelium. Moreover, deformities from contractures are frequent and *cannot* be prevented by holding the part in a natural position forcibly with splints, traction, and the like. Spontaneous healing of deep burns without the use of skin grafts is also defective because of the long period required for final healing. Indeed, large defects may persist for months or years with no evidence of healing.

Preparation for Skin Graft. Elimination of all necrotic tissue is a sine qua non for the application of skin grafts. In extensive burns, the devitalized tissue should be excised down to normal fat, fascia, or muscle in 7 to 10 days if the patient is in condition to stand a formidable operation and can be protected against shock by complete blood replacement (10). Chemical methods, including the use of proteolytic enzymes, have been tried and some of them are promising.

It cannot be emphasized too strongly that once a skin graft is indicated, it should be carried out as soon as possible. Delay merely prolongs disability and increases the nutritional and other complications. Moreover, serious or insidious infection is much more likely to develop. Finally, nutritional rehabilitation may be jeopardized in the presence of a large, granulating skin defect. Coverage of such a wound even with homografts (11) —from a donor or fresh cadaver—greatly accelerates nutritional recovery. Even the temporary life of such grafts is, therefore, of great importance in preparing the patient for final operation, using his own skin. A skin graft is indicated in most full-thickness burns more than 2 cm. in diameter, and on special areas like the fingers, face, feet, and hands, even when the defect is only 4 to 5 mm. in size after separation of the slough.

Skin Grafting. Skin transferred from one part of the body to another is called an autoplastic graft. Skin transferred from one in-

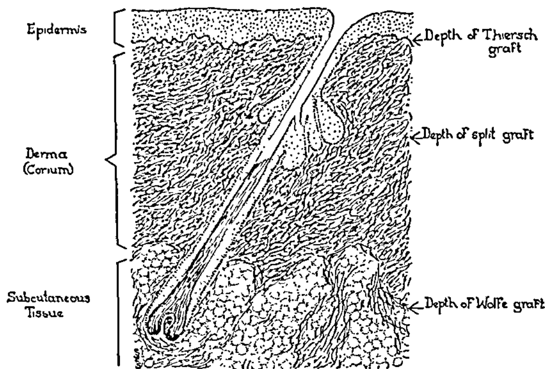


Fig. 9. Cross section of normal skin showing the approximate depth at which the various types of skin graft are cut.

dividual to another of the same species is a homoplastic graft or homograft, which has great value temporarily (see above) but is not permanently successful except in identical twins (11) or in individuals with agammaglobulinemia (12). Skin of different depth may be utilized (Fig. 9). A *free graft* is one in which the transplanted skin is completely removed and transferred to its new location. If the graft, though attached to its new bed, still retains a connection with its original site, the transplant is called a *pedicle graft* or *flap*. As soon as the flap establishes vascular connections with the new bed, the pedicle is cut and the transplantation is complete. This method of transplantation was used 400 years ago by Tagliacozzi. Free transplantation of skin was first performed by Reverdin, a Swiss surgeon who removed tiny pieces of skin (2 to 4 mm. in diameter) from one part of the body and placed them over the granulating defect. The method is still in wide use and can be easily and simply done, but is cosmetically imperfect and heals with much scar between the islands of skin. At the present time there are very few indications for the use of such grafts in the treatment of burns. Thiersch, also a pioneer in skin grafting, described the use of the razor to remove large, thin sheets of skin which included part of the germinative layer but left enough for regeneration to occur. As described and used by Blair and Brown (13), the split graft is a modification of the Thiersch graft and represents a great improvement because the greater thickness results in a graft which is not only more resistant to injury but also presents a more normal appearance. The regeneration which occurs so readily at the donor site takes place by growth of the epithelial cells in the hair follicles and sweat glands just as it does in the case of second-degree burns.

For the coverage of defects produced by deep burns, split-thickness grafts of skin with a dermatome should always be used (Figs. 10, 11). Small pieces of skin cut from a sheet in the form of postage stamps are better than small pieces taken by the Reverdin technic. Pedicle grafts are reserved for some late plastic operations or contractures. When large areas need to be grafted, it is



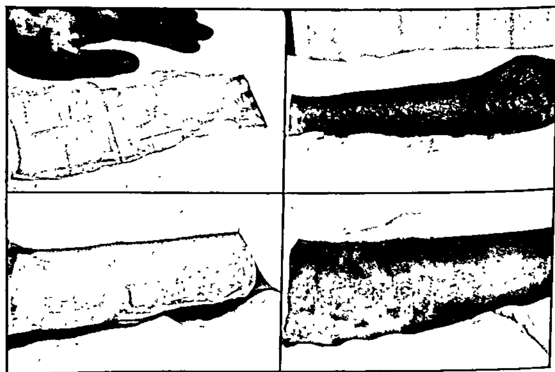
A B

Fig. 10. Padgett dermatome. A, a "three-quarter" thickness skin graft is being removed from the inner side of the right thigh; the part which has been cut is attached to the drum. B, the graft is being removed from the drum; it is 4 x 8 inches in size, 0.02 inches thick. The patient was a young woman aged 24; the graft was placed in a large denuded aseptic area on her chest. (After Padgett, Ann. Surg.)

important to take with the dermatome not more than 160 square inches at one time and to make them very thin. Thin grafts heal rapidly and, moreover, permit use of the same donor sites over again in about four weeks.

If burns are allowed to heal without the application of skin grafts at the appropriate time (usually 12 to 16 days after the burn),

A B



C D

Fig. 11. A, cut dermatome graft with nylon backing. Note limpness of graft, yet normal tension of skin maintained. B. recipient site ready for grafting. C, graft in place. Note absence of sutures. D, graft three weeks postoperatively. Note the excellent take. (From Green, Levenson, and Lund. New England J. Med.)



Fig. 12. Contracture of axillary skin following the healing of an extensive burn in a 19-year-old girl. The burn was sustained 10 years previously. Limitation of abduction of the arm is shown; complete mobility resulted after a plastic repair with skin graft.

contraction will develop (see Fig. 12). This contraction can, of course, be corrected by a plastic procedure excising the scar and applying a skin graft in the defect. When this procedure is carried out on the face or neck it is desirable to use a full-thickness graft because it will result in an appearance more nearly like the adjacent skin. In areas covered by clothing, a split-thickness graft is usually satisfactory.

Respiratory Burns. Patients who were trapped in burning buildings, or even in a single room, may suffer severe tracheal and pulmonary injuries from inhaling smoke and flame. The damage may involve the finer bronchioles. In such a fire as that in the Cocoanut Grove night club in Boston, the deaths of scores of patients were due primarily to pulmonary damage induced by the heated air itself or to toxic fumes related to phosgene (14). Some died immediately, others survived for a few hours or a few days at hospitals. Such patients need special therapy directed toward their respiratory symptoms. First consideration must be given to the indications for tracheotomy. Tracheotomy should be done if there is doubt as to its need. This permits direct suction for the relief of respiratory obstruction due to mucus. Humidification of the atmosphere of the patient's room is essential. The use of drugs for bronchial relaxation may also be indicated. Sedatives should be avoided or used with extreme care. Antibiotics will also prevent or control respiratory infection. The danger of excessive intravenous infusions in patients with pulmonary disturbances has already been mentioned.

CHEMICAL BURNS

Caustic alkali, acid, liquid bromine, and other chemicals produce but a superficial injury of the skin provided the contact is momentary. However, the degree of necrosis may be severe if the corrosive chemical is not promptly removed.

Treatment. Emergency therapy, if effective, will minimize the degree of necrosis. Prompt application of large amounts of water to the affected skin in order to dilute the chemical is probably better than any attempt at neutralization by the application of antagonistic substance. Thus Davidson (15), who has investigated the problem experimentally, found much less damage to the skin following the use of plain water than of any other material. The ready availability of water, moreover, also ensures its prompt use. Once the damage is done, the care of the injured area is the same as that for destruction of tissue by any other cause (see under Thermal Burns).

HEAT STROKE AND HEAT EXHAUSTION

These two diseases, despite the similarity in their names, are quite different, as discussed below. Both, however, may be present in the same patient and are due primarily to increases in environmental temperature and are chiefly of medical rather than of surgical interest, except that patients (and also personnel) may suffer therefrom during operations performed during hot weather. All patients should be observed carefully for evidence of heat exhaustion as well as heat stroke during severely hot weather; such preventive measures as ensuring adequate fluid and sodium chloride intake, as well as special nursing care, should be provided. Of even more importance is *the care of the patient in the operating room* during the operation itself; fatalities have been observed, undoubtedly due to the effects of excessive temperature and humidity. Care should be taken that no more sterile sheets be used over the patient than is absolutely necessary. Moreover, the patient must be watched meticulously during the operation, particularly for tachycardia and other evidences of circulatory changes. If such changes are noted, the patient's temperature should be taken. Extensively burned patients are very subject to the harmful effects of hot weather partly due to the loss of the cooling effects of normal perspiration, because of the large dressings and/or of the loss of such function in extensively damaged skin, and partly due to the deleterious effect of high environmental temperature in general on the mortality from burns (16). Hyperthermia generally indicates heat stroke and calls for immediate therapy (see below). Air-conditioning, which is becoming fairly prevalent, solves this problem.

1. *Heat stroke* (thermic fever, sunstroke) is seen during hot weather, especially when the temperature exceeds 100° F. (38° C.). The victims may lose consciousness, present a hot, flushed skin, full rapid pulse, and a high fever which may reach 110° F. (43.3° C.). There is obviously a disturbance of the heat-regulating mechanism. Studies of the blood chemistry showed no marked changes in the patients treated at the St. Louis City Hospital during the hot summer of 1934. A complete clinical study in the nearby city of Cincinnati was reported by Ferris and associates (17). Treatment is urgent and consists of rapid but careful reduction of the fever. Immersion in an ice-water bath is effective. The body temperature is carefully taken every few minutes and the patient removed when it has dropped to 102° F. (39° C.); the fall continues for some minutes. An efficient but slower method consists of covering the nude patient with wet sheets over which air from an electric fan is blowing. Sheets wet with alcohol will be more rapidly effective than those wet with water.

2. *Heat exhaustion*, which in reality consists of severe dehydration and sodium chloride depletion, is seen ordinarily in workmen confined to hot boiler rooms, in heavily clad, marching soldiers, or in any person in whom excessive perspiration leads to loss of water and salt but only water is ingested. This is similar to acute salt deficiency or water intoxication. After states of extreme sweating, McCord and Ferenbaugh (18) state that "in 24 hours the loss from the body of chlorides approximates 20 grams—an amount that certainly may not be replaced by chlorides normally in food and drinks." Victims of heat exhaustion at the Boulder Dam construction were studied by Talbott and Michelsen (19), who found a pronounced reduction in the blood chlorides of these patients. A detailed discussion of sweat losses will be found in a monograph by Kuno (20).

Symptoms come on gradually and include fatigue, cramps of muscles, abdominal pain, and, only in the worst cases, severe prostration. The clinical picture is greatly influenced by physical activity (20) which leads to the first-named symptoms, seldom seen in water intoxication. Even then, the picture is entirely different from that of heat stroke, i.e., the temperature is normal or subnormal, although slight elevations were noted. The skin is moist, pale, and cool and the pulse normal. Treatment is specific—sodium chloride. Heat exhaustion may be prevented by supplying sodium chloride (in the form of tablets) to individuals working under conditions producing excessive loss of body fluids through perspiration.

INJURIES DUE TO COLD

The systemic reactions to cold are those of shock and are produced only under conditions of extreme exposure, which are relatively rare. These accidental instances of hypothermia (21) have assumed wider significance in view of the use of induced reductions of body temperature. Recent studies on hypothermia have added much to our knowledge of this subject. Cardiac arrest and fibrillation are responsible for many of the fatalities, and become increasingly frequent *as the body temperature falls below 28° C.* (79° F.). More common are the local effects —usually on the extremities, nose, and ears —which vary in degree from slight injury to gangrene. Permanent effects are also seen and are of great importance.

Tissue injury, short of actual necrosis, is probably the most frequent effect of cold. Nevertheless, such injury, by secondary factors, may lead to necrosis of tissue. The key to an understanding of those secondary factors is in the vascular as well as in cellular response to cold, particularly when the exposed part is brought into a warm atmosphere. The primary response to the injury produced by cold is, of course, the usual inflammatory changes already described. These changes, however, cannot occur at once because of the cellular paralysis and vasoconstriction which results from cold. Inflammation due to injury from cold can occur only when the temperature returns to normal, i.e., when the chilled part is warmed. Vasodilatation and exudation then take place, swelling becomes marked, and vesicles appear in the skin just as if the part were burned. Much more serious may be the effect of cold on the veins and lymphatics (i.e., thrombosis) which interferes with rapid drainage of fluid. Exudation thus leads to tremendous pressure and swelling in the inflamed area, which may finally become great enough to occlude the arterial supply. As a final event actual gangrene may develop (Fig. 13).

Injury due to cold comprises various clinical types, as follows:

1. *Chilblains* or pernio is a mild inflammatory reaction which develops after exposure to cold, especially damp cold, even when slight in degree. In its severe form, scaling of the skin may follow, and even a local patch of gangrene may appear, which finally heals. *Certain patients are particularly susceptible* to chilblains after previous injury by cold. This may be due to the production of permanent alterations, vascular or neurogenic.

2. *Trench foot* is a form of chilblains seen in soldiers whose feet were exposed to damp cold for many days. It is similar to "immersion foot," described below. Blistering, edema, and areas of gangrene occurred. Healing of these lesions was often prolonged. Such feet often showed more or less permanent disability due to inadequate blood supply and were especially susceptible to further injury from cold.



Fig. 13. Frost bite of the toes. A, three days after exposure; note the marked inflammatory reaction. B, one month later, after spontaneous amputation of the dead tissue. The clean granulating surfaces rapidly epithelialized. Conservative therapy was used, i.e., elevation, rest and heat. The patient was a healthy 31-year-old male.

3. *Frostbite* is a term often applied to any injury due to cold. As used herein it refers to actual necrosis of tissue. Edema, blistering, and (later) evidence of infection may precede the necrosis or gangrene which not infrequently develops; following this, a line of demarcation forms and the dead part eventually sloughs off.

TREATMENT. Proper care of the feet in severely cold weather will prevent most of the ill effects of cold on the lower extremities. This was learned in World War II, especially by Russian soldiers who, in pairs, were required—often at gun point—to massage each other's feet at regular intervals in severe climatic conditions, especially damp cold. Once the part has been injured, the problem is that of preventing necrosis by thawing out all frozen tissue *slowly*. While this may be achieved by the ancient and still popular practice of rubbing the part with snow or cold water, such a procedure is *dangerous* and should not be utilized because it frequently leads to mechanical injury of the frozen tissue, which is friable and easily broken. Gentle heat must be applied carefully so that the skin surface is not injured thereby. Warming with water at 42° C. (104° F.) is a recommended procedure. If warm water is not available, the part can be safely warmed by placing it under dry clothes and against another person's body. Injections of heparin are also recommended and should be started within 24 hours (21).

Of great prophylactic importance, too, is adequate protection against damp and cold, especially in susceptible individuals. The anesthetic effect of cold always makes it a treacherous injurious agent, in that warming is thus impossible. Necrotic tissue is treated as if it were due to any other cause. Amputation is never advisable early in the process. Ordinarily the dead area sloughs off spontaneously, and the area of destruction is much smaller than that originally estimated. After the line of demarcation forms, the rapidity with which the dead tissue is cast off may be accelerated by gentle operative procedures.

Immersion Foot. Described by numerous observers in World War II, this condition is similar to and perhaps identical with the "trench foot" of World War I. The chief manifestation is swelling of the feet, which develops several hours or a few days after exposure to wet cold. It is encountered primarily in shipwreck survivors, particularly those who have been forced to sit in a lifeboat for several days with their feet dangling in cold water. The condition has been described in detail by Webster, Woolhouse, and Johnston (22); it develops only when the temperature of the water is about 55° F. or below, although it may occur in less severe forms with exposure to warmer water.

Clinical manifestations start a day or so after exposure and consist of pain, numbness, and tingling in the feet. Upon examination, they are found to be swollen and pallid, with scattered areas of cyanosis. After removal from the cold environment, swelling tends to increase and the pallidness changes to an erythematous color. The feet become unusually warm but do not sweat. The pulse remains palpable except when edema obliterates it. Blisters, of variable size, containing strawcolored or sanguinous fluid may appear. Local patches of gangrene may develop but are not extensive and usually require no more than local amputation (e.g., of the toes). However, if infection develops in the blisters, abrasions, fissures, and so forth, as it may do, definite threat may be made upon life, and amputation may become necessary.

The exudate of fluid (plasma) into the swollen feet may be so extensive as to lead to shock and, therefore, may actually be a primary cause of death in shipwrecked personnel.

Perhaps the most important feature in treatment is maintenance of a cool temperature about the feet. They should first be washed gently with soap and water to remove dirt, and the like, thereby minimizing the danger of infection. The feet should be kept uncovered and dry. The maintenance of a low temperature is essential because the increased oxidation created by elevated temperature takes place so rapidly that the metabolic demands in the injured extremities cannot be met. Before the patient is allowed out of bed, he should be given graduated exercises. If pain remains, the peripheral nerves may be crushed, as recommended by White (23). This interrupts nerve function

only temporarily inasmuch as regeneration will take place in about three months. However, the condition usually clears up within a few weeks without any special therapy.

Prophylaxis consists of keeping the feet dry and warm with rubber boots. Unfortunately this precautionary measure cannot be made available to all those likely to be set adrift at sea. In addition to keeping the feet dry, application of grease or heavy oil also aids in preventing the disease by acting as a protective covering. Frequent exercise of the extremity is likewise very helpful as a preventive measure. When victims are rescued, they should not be allowed to walk lest the trauma of weight-bearing result in serious damage to the already edematous and damaged tissues of the feet. Prevention of infection is likewise extremely important.

Painful swelling of the feet also occurs in men who are shipwrecked in warm waters. The process does not proceed to as severe a state as in the typical immersion foot syndrome, but may become serious when the victim has been exposed for several weeks. After a study of several cases, White (23) concluded that one of the chief causes of the swelling occurring under such circumstances was a vitamin and protein deficiency. It is assumed that the excess heat, continued exercises (created by bailing, rowing, and so forth), along with dehydration and starvation, result in a vitamin deficiency and hypoproteinemia within a relatively short time.

X-RAY AND RADIUM BURNS

Injurious effects of x-rays and radium are used therapeutically to destroy malignant or other neoplasms. Sometimes normal tissue is intentionally injured in order to achieve this end. Accidental or unintentional burns or injuries to skin by x-ray and radium occurred in the early days of radiotherapy and are still encountered after its inexpert use. The first effects of severe x-ray injury are not evident immediately, but are manifested in about a week or 10 days and consist of hyperemia, tanning, and exfoliation. Serious lesions may occur many years later and consist of indolent ulcerations which do not heal (Fig. 14), become malignant, and lead finally to death. General effects of x-ray therapy also occur within a few hours following a treatment and produce a syndrome which is called roentgen sickness. Nausea and vomiting, asthenia, and headache are the usual symptoms.

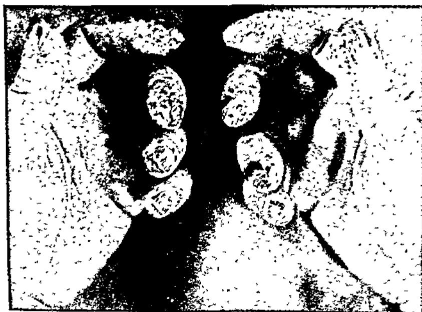


Fig. 14. X-ray burn of hands. This lesion was produced by exposure to x-ray frequently and over a long period of time. Even though exposure is stopped, the lesion may progress and go on to malignant degeneration. (From Deryl Hart in Practitioners Library, D. Appleton-Century.)

Treatment of the ulcerated lesion consists of excision and application of a skin graft. Obviously prophylaxis is most important; use of x-ray and radium should be confined to expert radiologists.

ATOMIC BURNS

Anyone exposed within five miles of the explosion of an atomic or hydrogen bomb may suffer intense burns from heat waves or from ionizing radiation. The former produces effects similar to those of the sun, treatment of which is identical with the treatment of any superficial burn of the same extent and depth (24).

Burns produced by ionizing radiations are very different and cause injuries that have seldom been observed previously except in an experimental animal, which has been given total body x-radiation. When the whole body is exposed to these penetrating rays, internal injuries of a lethal nature follow if the dose is much over 700 roentgen units. The greatest damage is found in the hemopoietic and lymphatic systems, but the gastrointestinal system and all glands are also severely injured. Clinical manifestations consist of nausea, vomiting, purpura, agranulocytosis, and toxemia. Patients who have received sublethal doses may be greatly helped by transfusions, by high protein, high vitamin diets, and by antibiotics. The latter must be given so as not to cause exacerbation of the diarrhea so often associated with the original injury (25). Because of gastrointestinal difficulties, it may be necessary to use the parenteral route to provide nutrition, perhaps for several weeks, until the acute phase is over.

Because of the great numbers of injured persons who might need medical help after an atomic explosion, adequate first-aid transportation and simple mass therapy assume obvious importance and imply the need for careful preparatory organization. This is also true of mass civilian casualties from fire, as evidenced in the tragedy at the Cocoanut Grove in Boston (14). A more recent experience, though with a smaller number of casualties, occurred in Buffalo and has been briefly described (26).

THE EFFECTS OF ELECTRICITY

An electric current in contact with the skin produces reactions which vary widely, depending upon its method of introduction into the body, the voltage, amperage, and kind of current (alternating or direct), on the variety of alternation, and especially on the thickness and moisture of the skin at the points of contact. Obviously, not all electric currents are damaging; many of them have beneficial therapeutic effects and are used in a variety of ways. In general, medium-high voltage currents are the most likely to cause injury.

Accidental electric injuries may be local or general. The *local effects* occur, for the most part, at the site of entrance and exit of the current and, depending on various factors, produce a superficial localized burn or a deep and extensive coagulation of tissue. The necrosis of tissue may be due to the heat generated by the passage of the current or to a direct effect of the current itself. Sometimes the clothes are ignited and typical flame burns complicate the electric injury. Undoubtedly both factors play a role, for even if the local lesion is charred and resembles an ordinary burn, it is apt to become indolent and heal very slowly, suggesting neurotrophic injury. The local lesions are treated as are burns due to any other cause. The extent of necrosis usually is apparent from the grayish color of the damaged skin but may be of much greater extent than first suspected. Tissue beyond an apparently sharp line of demarcation, which appears healthy, may show evidence of inadequate healing weeks or months later. In excising damaged tissue, a wide margin of normal tissue, therefore, should be removed if possible.

The *general effects* of electricity are apt to occur only if the current passes through the central nervous system or heart. Langworthy (27) has studied two electrocuted criminals and found marked changes in the cells of the medullary center concerned with respiration. The clinical manifestations of electric shock are, in most cases, due to respiratory paralysis. Unconsciousness and circulatory impairment are frequently present early. When this happens, artificial respiration must be started within six minutes if the patient is to have any chance of survival. Further treatment is that

of shock in general but, in addition, should include persistent artificial respiration, which should be continued for hours if the circulation is maintained. Obviously, if the medullary cells are merely injured, recovery is possible; if damaged beyond repair, death is inevitable. Since evidence of cerebral edema has been noted, some recommend lumbar puncture and the intravenous injection of hypertonic solutions.

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16

THE EMERGENCY SERVICE AND THE ACUTELY ILL OR INJURED PATIENT

John Schneewind

THE EMERGENCY SERVICE

A well-organized, smoothly running Emergency Service has become an integral part of almost every hospital. This is true not only because acute, severe injuries are increasing due to automobile accidents, and so forth, but because of the obvious need for rapid, efficient treatment for the nonsurgical emergencies as well. Furthermore, every hospital administrator now realizes the need for a carefully organized disaster plan to cope with a sudden influx of many casualties of a tornado, train accident, or the like; the Emergency Service occupies a key position in the management of these patients. The threat of a national disaster due to air attack is another reason for the need of an Emergency Unit as the hub of a disaster plan.

Adequate facilities and personnel are essential to ensure good treatment to the injured or ill patient. The Emergency Service should be in an accessible location where auto and ambulance traffc may be controlled efficiently, and where hospital personnel or anxious relatives will not impede patient movement. Figure 1 illustrates the space set aside for the Emergency Service at the University of Illinois Hospitals. In addition to several examining rooms, there are a nurses' station, a doctors' office, a laboratory, a small x-ray unit, two operating rooms, and two observation wards each containing two beds. These overnight wards are invaluable for allowing repeated examinations of difficult diagr problems and for determining the nee hospitalization. They are also helpful i lowing performance of such ancillary ser as blood transfusions to outpatients du slack periods.

Personnel. It is important that some m ber of the staff be appointed chief of the se ice and be directly concerned with its vari administrative and medical problems. Pr erably, this should be one of the youn members of the surgical staff rather than busy department head. The chief of t Emergency Service should drop in at lea once and preferably several times a day, eve if only for a short time. He may examine a acutely ill patient and assist in establishin the diagnosis, may help with a difficult dis position problem, or may scrub up and assis in suturing a difficult laceration. He must be sure that each hospital department provides adequate coverage for the Emergency Service 24 hours a day. At the Research and Educational Hospitals three interns are assigned to Emergency each month and rotate through eight-hour shifts. During such peak periods as Friday and Saturday nights, a call man is in the hospital and available should the intern on duty be unable to handle the load. A resident from each department is on call at all times for consultation regarding the management of Emergency Service cases. The intern is encouraged to call the resident for all pa-

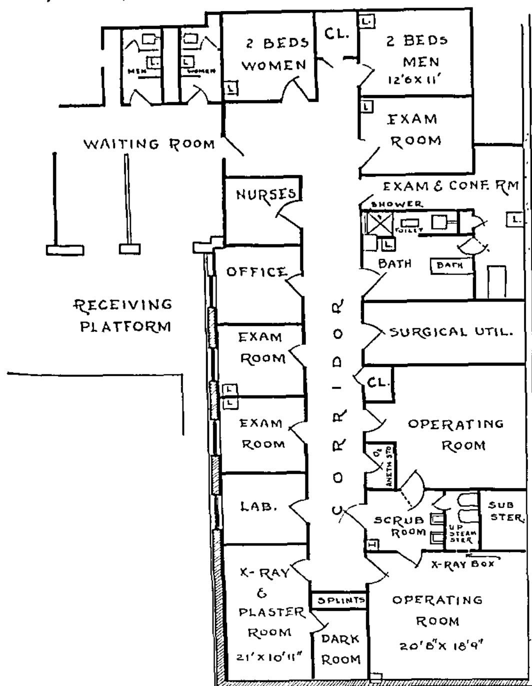


Fig. 1. Floor plan of the Emergency Service at the Research and Educational Hospitals, University of Illinois, College of Medicine.

tients with significant injury or disease. The resident, in turn, calls an attending physician for complicated cases or those requiring a major operation. It should be noted that the majority of cases are handled by the interns and residents and help from the attending men usually is not required.

Emergency Service Manual. One of the problems in maintaining an efficient standard of treatment is the constant rotation of interns each month. We have found it helpful to compile a manual which includes General Rules, Treatment of Wounds, Treatment of Burns, Prophylactic Treatment of Tetanus, a Mul-

tiple Casualty plan, and such miscellaneous items as scrub technique (1). The new interns are met a few days before they go on service and the above material is discussed, together with such other problems as the medicolegal aspect of treatment in the Emergency Room and the management of inebriated patients with head injuries. In addition to our own directives, we have found the monographs on soft tissue injuries and fractures prepared by the American College of Surgeons' Committee on Trauma (2, 3) most helpful.

Although injuries in industry are decreasing in number, accidents in other activities appear to be increasing (see also Ch. 14). For this reason, adequate facilities must be maintained for taking care of emergencies and, of more importance, increased efforts must be made in the teaching of trauma (4).

THE ACUTELY ILL OR INJURED PATIENT

General Considerations. On admission to the Emergency Room, the state of consciousness of the seriously ill or injured patient determines, to a great extent, the amount of information which may be obtained regarding the circumstances of the illness or accident. The prostrate, more or less unconscious patient always presents a complicated diagnostic problem, the solution of which is often urgent because of the necessity of instituting lifesaving treatment. Superficially, such a patient may present a similar clinical appearance whether he is suffering from traumatic shock, alcoholism, diabetic coma, concussion of the brain, uremia, or the like. It is always hazardous to disregard the possibility of intracranial injury merely because the patient has the odor of alcohol on his breath. The sensorial depression may be minimal or there may be complete lack of response to sensory stimulation, in which case the patient is considered to be comatose. A comatose patient, while ordinarily quiet and immobile, may, at times, be restless or exhibit convulsive movements or uncontrolled activity. Such a state may be a sign of cerebral injury or increased intracranial pressure.

In addition to careful evaluation of the state of consciousness, certain other basic principles in the management of acute patients are almost always of great value. Traumatic cases may have a short period in which they are quite responsive and then lapse into profound depression, and the examiner must take advantage of these opportunities. Repeated examination of the patient with a suspected "acute abdomen" is also valuable, since pain and muscle spasm may change significantly in a very short period.

Minimal and gentle handling is axiomatic in treating emergency cases. This is especially true during the initial examination when such an obviously superficial injury as a bleeding scalp laceration may distract attention from a fractured cervical spine or a lacerated spleen due to blunt trauma to the abdomen. Injudicious movement may accentuate shock, stir up quiescent hemorrhage, or cause severe spinal cord damage.

"First things first" is another axiom which must be observed. The cleansing and dressing of a patient with severe burns prior to institution of treatment of burn shock may spell disaster. Treatment of obvious fractures while active hemorrhage from a lacerated spleen proceeds undetected is an error too commonly made.

It is advantageous, perhaps, to attempt to classify some of the diseases which are capable of producing more or less complete loss of consciousness and other evidence of sensorial dysfunction, since they may present difficult diagnostic problems.

I. Circulatory Shock

This may produce severe prostration and varying degrees of cerebral dysfunction due to the general circulatory impairment and cerebral anemia. Some of the causes are:

1. Hemorrhage
2. Trauma, including fractures
3. Burns
4. Exposure
5. Myocardial infarction and heart failure
6. Cardiac tamponade

II. Intracranial Lesions

These may produce more evident sensorial depression, often coma and convulsions, and sometimes restlessness and delirium. Such disturbances are due to actual cerebral injury or obstruction to

outflow of cerebrospinal fluid and may be caused by:

1. Trauma
2. Apoplexy or vascular spasm
3. Embolism
4. Tumors
5. Infection

III. Physiochemical Coma

This group is concerned with the effect of deranged intrinsic physiology or extrinsic poisons on the cerebral cells. Included are:

1. Alcoholism, poisons
2. Diabetic coma, insulin shock
3. Uremia due to urinary obstruction (enlarged prostrate, stone, etc.), kidney disease
4. Dehydration and electrolytic depletion due to vomiting, diarrhea, fistulas, starvation, etc.
5. Severe illness due to septicemia, advanced intestinal obstruction, gangrene of the extremities, hepatic disease, and severe jaundice
6. Various types of psychoses

Further details concerning these three groups will be found in Table 1, which lists many of their pathologic and clinical differences. A more complete description will be given in the text after considering some gen-

TABLE 1. The Acutely Ill or Injured Patient (Common Causes of Sensorial Depression)

	Shock	Intracranial Lesions	Physiochemical Disease
Etiology	Hemorrhage Trauma, including fractures Burns Myocardial infarction Heart failure Cardiac tamponade	Trauma to brain tissue and increased intracranial pressure; i.e., injury, hemorrhage, edema, tumor, infections	Poisoning, uremia, profound infections and toxemia, dehydration, hypoglycemia and hyperglycemia, psychosis, asphyxia, hepatic disease, electrolyte depletion (i.e., sodium, chloride, and potassium)
Pathogenesis	Low blood pressure due to low blood volume or ineffective propulsion	Direct brain damage; cerebral anemia due to increased intracranial pressure	Toxic action on brain; abnormal cerebral function
Clinical picture	1. Low blood pressure 2. Fast, thready pulse 3. Respirations may be *shallow; air hunger in* hemorrhage 4. Subnormal temperature 5. Slight to moderate sensorial depression 6. Restlessness and thirst in hemorrhage 7. Pallor 8. Collapsed veins	1. Varied blood pressure 2. Full pulse; may be slow 3. *Irregular respirations* 4. Normal or elevated temperature 5. Coma, hyperactivity, convulsions 6. Pathologic neurological signs 7. Choked disk 8. If traumatic, scalp lacerations, fractured skull, etc. 9. Abnormal spinal fluid	1. Normal or high blood pressure 2. Full pulse; may be fast 3. Variable respirations (Cheyne-Stokes, air hunger, etc.) 4. Normal or elevated temperature 5. Deep coma, convulsions, delirium 6 Special signs as revealed by odor of breath, bladder dullness and rectal examination, urine and blood examination, etc. 7. In sodium and potassium depletion, may have hypotension and/or mental apathy even to coma
Emergency treatment	Clear airway Control of hemorrhage, rest, warmth, sedatives, fluids, transfusion, oxygen	Clear airway Intravenous fluids and transfusions as indicated	Gastric lavage, insulin, glucose, catheterization, fluids (especially sodium and potassium), artificial respiration, lumbar puncture, etc.

eral points in the physical examination of these prostrate patients.

PHYSICAL EXAMINATION OF THE ACUTELY ILL OR INJURED PATIENT

It is essential that the Emergency Room physician master the technic of a rapid yet thorough examination of the acutely ill patient. Although detailed examination is impossible, it is surprising how much information can be obtained by a systematic approach.

Initial Inspection. In the initial inspection, the examiner should look for evidence of severe illness or injury requiring immediate attention. If there are no indications for immediate therapy, the physician may proceed with a more detailed examination as described below. Cardinal points of crucial importance are:

1. *Is the Patient Breathing?* The examiner must be sure the tongue is forward and that vomitus, mucus, or blood is not blocking the airway. The presence of a collapsed lung due to pneumothorax or severe chest injury may be the very first thing to treat.

2. *Is the Patient Bleeding?* Immediate control of obvious accessible hemorrhage by a pressure dressing is mandatory.

3. *Is the Patient in Shock?* With airway cleared and hemorrhage controlled, intravenous administration of fluids such as dextran, plasma, or whole blood is required to treat circulatory deficiency, usually present or imminent in a severely injured patient.

4. *Is There a Severe Wound?* Severe wounds require immediate attention, especially when there is acute bleeding. The bleeding must be controlled by a pressure dressing or temporary application of a tourniquet in the case of a severed artery in an extremity. If the airway is clear and shock therapy has been instituted, the following points should be ascertained:

a. Time Interval. The extent of elapsed time since infliction of the wound will affect the method of treatment.

b. Location and Extent. The severity of trauma is influenced by the size and location of the wound in relation to nearby vital structures. Small neck wounds may cause respiratory obstruction or injury to blood vessels, cervical cord, pharynx, or esophagus. Thoracic injuries may fracture ribs, sever intercostal or mammary vessels, or penetrate lungs, heart, trachea, or esophagus. Penetrating injuries low in the chest commonly lacerate spleen, stomach, liver, and colon. Abdominal wounds may involve such retroperitoneal structures as kidneys and vena cava as well as the intraperitoneal viscera. Wounds in the extremities may involve tendons, nerves, and large vessels.

c. Type of Wound. It is important to note whether the wound is blunt or penetrating in type and whether it is a clean, incised wound or a crushing injury with severe contamination. Puncture and human bite wounds are usually not primarily sutured, in contrast to incised wounds of recent origin.

5. *Is There a Fracture Deformity?* Inspection may reveal swelling, echymoses, or an obvious deformity. Point tenderness, false motion, crepitus, bony irregularity, and loss of function are other signs of a fracture which may be present. Multiple rib fractures may be associated with intrathoracic injury and bleeding into the pleural space, with pneumothorax due to puncture of the lung, or, in very severe injuries, with a flail chest and paradoxical respiratory motion.

6. *Is Sensorium Affected?* It has been noted above that loss of consciousness may be due to some pre-existing disease or to intracranial trauma at the time of injury. At any rate, the state of consciousness is often an index of the seriousness of the illness or injury.

Brief History. After the cardinal points relative to the vital processes of respiration and circulation have been ascertained, a rapid, brief history of the accident or illness should be obtained from the patient by direct questioning if he is able to respond coherently. It may be necessary to obtain the information from a witness to the accident or from a member of the family. Important points which must be established are: 1. state of consciousness prior to and following injury or illness; 2. pre-existing disease or disability; and 3. previous treatment rendered—especially relative to administration of narcotics. If, for example, the patient has sustained a head injury, inability to recall the

details of the accident or transient loss of consciousness may be the initial sign of significant brain injury associated with extradural or subdural bleeding. In the case of gunshot or stab wounds, it is important to establish the relative positions of assailant and patient in order to get an idea of which organs may have been injured. It is also obvious that a past history of coronary thrombosis, stroke, diabetes, and the like, may change the whole method of diagnosis and treatment of the current episode.

Orderly, Thorough Examination. The physician should do a rapid, thorough examination now that he knows that the patient's life is not in immediate danger and he has some idea of what he may encounter and what aspects of the examination will require an assiduous search. The routine of examination is not as important as the consistency in following some systematic method. One method is to begin with pulse, temperature, respiratory rate, and blood pressure (if not already determined). Not only the rate but the force and rhythm of the pulse should be checked. Color, temperature, and moisture of the skin should also be noted.

HEAD AND NECK. Inspection and palpation of the scalp for possible lacerations or fractures may be followed by systematic palpation of facial bones and mandible, especially if there is a history of head or facial trauma. The relative size of pupils, response to light, fixation of gaze, and color of scleras may then be noted. Ears and nose should be checked for bleeding or for leakage of cerebrospinal fluid. Mouth and tongue are inspected for lacerations, loose teeth, bleeding, and so forth.

Injury to the cervical spine may be revealed by visible or palpable deformity, tenderness, and echymosis. The presence of such an injury requires a rapid motor, sensory, and reflex examination. Prior to any movement of the patient, the head must be supported to prevent lateral deviation or torsion. In the absence of cervical spine injury, the neck may be flexed to determine whether rigidity or tenderness is present. Further examination of the neck may reveal enlarged lymph nodes, tracheal deviation, hematomas, or emphysema. The head should be flexed for determination of neck rigidity or tenderness.

THORAX. Inspection of the chest should include notation of rate and depth of respiration, and asymmetry or inequality of expansion such as is found in significant pneumothorax, massive collapse, or large pleural effusion. The bony framework including clavicles, ribs, and spine should be inspected and palpated. The patient may be gently rolled from side to side for this purpose, but not if he has a fracture of the spine. Auscultation and percussion of lungs and heart may then be done.

ABDOMEN. Examination of the abdomen may begin with palpation of the costovertebral angles to elicit tenderness over the kidneys. Compression of the pelvic girdle may cause pain if there is bone injury. Inspection of the abdomen may reveal distention caused by intestinal obstruction, ascites due to cirrhosis, peritonitis, metastatic cancer, and so forth, or localized tumor masses. Palpation should always proceed from the least tender area to the painful area and must always be gentle. Localized muscle spasm may be a sign of acute appendicitis or cholecystitis; rebound tenderness usually denotes inflammation of the parietal peritoneum. A globular, tender, right upper quadrant mass may be a hydrops of the gallbladder caused by a blocked cystic duct. Each quadrant of the abdomen should be examined, using bimanual palpation when necessary to help the examiner feel liver, spleen, kidneys, and so forth. Character and rate of bowel sounds and presence of bruits, as in abdominal aortic aneurysms, may then be determined. The presence of ventral, inguinal, or femoral hernias may be noted; for this purpose it may be necessary to have the patient stand, assuming that no contraindication for this position is present.

GENITALIA. When a gynecologic examination is indicated, the external genitalia should be inspected and palpated, followed by speculum examination of the vagina and cervix. A gram stain of vaginal secretions may reveal gram-negative intracellular organisms, which is very helpful in the differentiation of acute appendicitis from pelvic inflammatory disease. Significant tenderness on moving the

cervix also indicates pelvic inflammation. Bimanual examination of uterus and adnexa should be included. In males, the scrotum should be inspected and palpated for evidence of orchitis, epididymitis, hydrocele, tumors, and the like.

RECTAL EXAMINATION. A rapid inspection of the anal verge may reveal external hemorrhoids, fistula, or fissure. Digital examination should note sphincter tone and may reveal intraluminal or extraluminal masses due to tumors or an inflammatory process. Metastatic growths may produce a shelflike projection of the anterior rectal wall. In women, the rectovaginal septum, and in men, prostate and seminal vesicles, should be felt.

EXTREMITIES. Simple inspection of an extremity may be diagnostic if there is obvious deformity, loss of function, swelling, or ecchymoses. Some of these signs are usually present if the injury is significant. The presence of cyanosis, edema, or the red streaks of lymphangitis should be noted. Palpation should show the presence of arterial pulses and, in the case of bone injury, may reveal local tenderness, false motion, crepitus, or muscle spasm. These maneuvers must be performed very gently.

In the case of lacerations and other wounds of the hands and fingers where tendon or nerve injury may be present, a most painstaking examination is necessary to evaluate correctly the extent of injury. The location of the wound is a valuable guide to the examiner. In injuries to the deep flexors of the fingers, there is inability to flex the distal phalanx; however, the examiner must immobilize the middle phalanx to obtain an accurate test. Similarly, inability to flex the distal phalanx of the thumb when the proximal phalanx is held immobile indicates a severed flexor pollicis longus tendon. In the case of wounds in the proximal finger area or palm, lack of flexion with the metacarpophalangeal point fixed indicates that both tendons have been cut.

Severed extensor tendons near the knuckles are common and, in this case, the patient cannot hyperextend the metacarpophalangeal joint with the interphalangeal joints flexed (as in striking a piano key). If an extensor tendon is cut near the distal interphalangeal joint, the patient may exhibit the so-called mallet finger deformity, i.e., the inability to extend the distal phalanx. In injuries of the thumb, if there is inability to extend the distal phalanx with the proximal phalanx immobile, the long extensor has been severed. If the patient suffers injury to the motor branch of the ulnar nerve in the palm, he will be unable to abduct or adduct the fingers when they are placed on a flat surface due to loss of interosseous muscle innervation. There also will be inability to "sweep" the thumb across the palm to the base of the fifth finger due to loss of the adductor pollicis muscle. If the motor branch of the median nerve is injured, the patient will be unable to lift the thumb normally or oppose it to the finger tips due to loss of short abductor and opponens muscle function. The usual sensory distribution of the ulnar nerve to the fifth and ulnar side of the fourth finger, and median to the rest of the digits, enables the examiner to assay possible injuries to sensory nerves.

If the patient's illness is due to involvement of the brain and spinal cord, a rapid neurological examination may be performed. For significance of findings, therapy, etc., the reader is referred to Chapter 27.

Acutely ill children and infants may comprise an appreciable percentage of the patients brought to the emergency service. Details of the examination of these young patients may be found in one of the standard pediatric textbooks.

SIGNIFICANCE OF COMMON ABNORMAL FINDINGS

General Appearance. As noted above, the initial rapid observation should reveal the presence of hemorrhage, shock, or asphyxia, for each requires prompt emergency treatment. The skin, if pale and cold, indicates shock; if cyanotic, suggests cardiac or respiratory disease; if grayish and pale, lead poisoning. The breath is frequently a great source of information. The sweet odor of acetone, the fetid breath of uremia, or the fecal odor in late intestinal obstruction may suggest the correct diagnosis at once.

Changes in the Sensorium. Sensorial changes indicate the degree of coma and can be determined by the response elicited by

such stimuli as pressure over the supraorbital nerve, the corneal reflex, or dilatation of the rectal sphincter. Hysterical patients, for example, will seldom fail to react to one or the other of these stimuli. In shock, unconsciousness is slight and ordinarily the patient will respond to such simple stimuli as pinching the skin. Deep coma with no response may indicate profound shock but is more commonly due to cerebral injury, uremia, or poisoning. Delirium or convulsive movements (especially in children) may accompany coma in severe infections, intoxication, or disease of the brain. In psychoses, the coma will be inconstant and often accompanied by peculiar behavior. In head injuries, an uncontrollable hyperactivity sometimes amounting to actual mania may be present. It is also seen in psychoses. In most instances, the depth of the coma, however, has been of little diagnostic aid (Solomon and Aring, 5). Increased intrapericardial pressure (cardiac tamponade) due to hemorrhage from wounds of the heart usually produces a delirium with muscular hyperactivity. Electrolyte depletion may result in depressed sensorium, especially in potassium loss (6), or even in coma, especially in sodium chloride loss (7).

Changes in Respiration. Abnormal breathing sometimes gives a clue as to the diagnosis. A very slow rate, five or ten respirations per minute, suggests morphine poisoning. Rapid, shallow respirations are common in shock; those deep and eager (air hunger) may indicate serious hemorrhage but are most notable in diabetic coma as a symptom of acidosis. Irregular breathing, such as Biot's or Cheyne-Stokes, indicates a cerebral lesion, either traumatic or secondary (cerebral edema) to an infection or uremia. When respirations are forced and accompanied by exaggerated use of all the accessory muscles of respiration, a physical obstruction is probably present in the larynx or trachea (exudate, spasm, edema, foreign body, or tumor), and explains the cause of cyanosis. Cyanosis and increased respiratory rate may be manifestations of cardiac disease; dyspnea and orthopnea may give the clue. Pulmonary edema or pneumonia may also cause an increased respiratory rate; pulmonary signs may be present on examination of the chest.

Changes in Temperature. A body temperature below normal points to shock; it is elevated, of course, in most severe infections, although in sepsis the low point may be subnormal, usually in the morning. An unusually high temperature is found in sunstroke and occasionally in intracranial lesions, particularly in terminal stages.

Miscellaneous Signs. Numerous miscellaneous signs may be of much diagnostic value. Argyll-Robertson pupils (lost reaction to light with retention of accommodation) point to tabes; pinpoint pupils to morphinism. In deep coma, however, examination of the eyes is apt to be unrewarding, since the pupils are often abnormal, regardless of the cause (Solomon and Aring, 5); this is true also of the reflexes. Ophthalmoscopic examination may reveal papilledema, indicative of increased intracranial pressure; retinal hemorrhages are present in nephritis, diabetes, etc. Hemorrhage from the ears or nose, especially the former, suggests basal fracture of the skull. Scalp lacerations may accompany or reveal a fracture of the skull; there may be an escape of cerebrospinal fluid or actual brain tissue in the wound. Cerebrospinal fluid draining from the nose or ear indicates a serious injury to bone and meninges because of the location at the base of the skull. Mouth burns indicate the swallowing of caustic poisons; spasm of the masseter muscle, laryngeal spasm, and risus sardonicus point to tetanus. Stippling along the gums (lead lines) are diagnostic of lead poisoning. Percussion of bladder dullness may indicate prostatic obstruction. This is made more plausible by the palpation of an enlarged prostate per rectum; catheterization may yield a liter or more of urine in such cases. Gastric lavage may reveal contents indicative of poison. Neurological signs indicative of disease of the brain and spinal cord should be looked for in questionable cases. Important are the sensory and motor disturbances when obtainable.

Laboratory Tests. Frequently, laboratory tests are the only means of making a diagnosis. Examination of urine, usually obtained by catheter, may reveal sugar (diabetes), casts, albumin (nephritis), pus (infection),

or blood (bichloride poisoning). The usual routine blood examinations are carried out and may show a high red cell count in dehydration, shock, and polycythemia, or a low count in hemorrhage. Stippling of the red cells indicates lead poisoning; plasmodia are diagnostic of malaria. Leukocytosis is present in serious infections and leukemia. Blood may be examined also for its sugar content to determine whether hypoglycemia or hyperglycemia is present. In uremia there will be an increased nonprotein nitrogen content of the blood. The blood chlorides paradoxically may be low in dehydration when there has been excessive loss of intestinal secretion from vomiting, diarrhea, and the like. A white cell count may be indicated in acute appendicitis. The serum amylase test may be very helpful when acute pancreatitis is being considered, as a high reading is usually diagnostic. It must be realized that moderate elevations are frequently encountered in intestinal obstruction and perforations of the gastrointestinal tract and must be interpreted correctly so that operative intervention, when indicated, is not delayed.

CIRCULATORY SHOCK

Although an entire chapter has been devoted to the subject of shock and hemorrhage, some of the cardinal points may bear repetition. Such obvious trauma as hemorrhage from severe lacerations, penetrating wounds of the chest or abdomen, fractures, and burns will be the cause of shock in most patients brought to the Emergency Service. The cause of shock in patients with blunt trauma to the thorax and abdomen is usually more difficult to diagnose and may be due to injuries to the spleen, kidney, or liver, or rupture of a hollow viscus such as gastrointestinal tract or urinary bladder. The onset of shock may be insidious in these patients and repeated examinations by an alert physician are required for early diagnosis. It is axiomatic that shock should be treated as early as possible, since the patient responds much more readily if treated before the manifestations have become prominent.

Conditions other than trauma which may cause shock, or at least a shocklike state, are insulin hypoglycemia, anaphylactic reactions, heart failure due to myocardial or coronary disease, and overwhelming infections.

Clinical Manifestations of Shock. The general appearance of the typically severe case is that of a seriously ill patient. The skin is cold, wet, and pallid; the extremities are cold; the lips are pale. The sensorium may vary from moderate dullness and apathy to a semicomatose state. Peripheral circulatory impairment is characterized by collapsed veins, rapid, thready pulse, and falling blood pressure. Temperature is often down a degree or two and respirations may be shallow and rapid. Hematocrit determination may be normal or reduced depending upon the mechanism of the shock. In the cases of shock due to hemorrhage, the hematocrit will be reduced if hemodilution has occurred as a compensatory effort to restore circulating blood volume. The white cell count often rises a few hours after trauma, especially when hemorrhage has occurred.

Treatment of Shock. It is possible to outline certain principles in the treatment of shock, but these must be modified in any specific case depending upon the clinical cause. The patient in acute heart failure will not tolerate large amounts of intravenous fluids whereas this may be lifesaving in the acute burn patient.

1. PREVENTION OF SHOCK. The early signs of impending shock may be very minimal. Slight tachycardia, perspiration or a feeling of faintness following positional change (as after sitting up), restlessness, or thirst may be all that is present, but should be honored by prompt institution of intravenous therapy.

2. CONTROL OF HEMORRHAGE. Obvious, accessible hemorrhage usually can be controlled by occlusive dressings. Tourniquets are rarely indicated and may cause damage if not released every few minutes. Bleeding from the lung following a penetrating injury usually will subside in a short time but must not be confused with hemorrhage from the chest wall, which may require operative intervention. Prompt celiotomy is almost always indicated in cases of intraperitoneal bleeding, whereas retroperitoneal hemorrhage, including that of the contused or lacerated kidney, is usually best treated by careful observation in the early period following injury.

3. Intravenous Fluids. Whole blood remains the colloid of choice in the treatment of shock due to hemorrhage; however, a plasma expander is an excellent substitute during the period of typing and crossmatching. It is usually quite safe to administer up to 2 liters of plasma expander, but additional needs should be furnished by whole blood. Slaney (8) has shown experimentally that, although one of the plasma expanders is very effective as a blood substitute following moderate hemorrhage, subsequent bleeding must be treated by whole blood infusion, especially when operation is contemplated. Animals receiving large quantities of plasma expander showed reduced tolerance to surgical stress when compared with animals resuscitated with whole blood. Saline and glucose may be used with at least temporary benefit if blood, plasma, or expander cannot be obtained immediately. Glucose alone is contraindicated because it results in rapid loss of electrolytes; moreover, the water injected without salt is poorly retained.

Other measures which may be helpful include conservation of body heat, bed rest, and relief of pain. Although theoretically the dilatation of cutaneous vessels might add to the circulatory imbalance, the patient usually feels better if cold, wet clothing is removed and he is given warm blankets. Bed rest is very important. Even moderate movement of a patient close to decompensated shock will precipitate sweating, tachycardia, and a fall in the blood pressure. Relief of pain by appropriate splinting of injured extremities and the judicious use of sedatives or analgesics may also be helpful.

INTRACRANIAL LESIONS

Most of the important intracranial lesions seen in an emergency room are traumatic. When severe symptoms are produced immediately, direct damage to the brain is usually present. Not infrequently, however, symptoms develop more slowly because they are due to a secondary rise in intracranial pressure (see Ch. 27).

Increased intracranial pressure produces symptoms not only because of the direct effect of pressure on nerve centers or tracts but also because of the associated cerebral anemia which it produces. Convulsions, when they occur, are probably due to cortical stimulation, usually by the same lesion causing the increased pressure. Uncontrollable hyperactivity is also seen in head injuries and is presumably due to the same cause.

Etiological Factors. The traumatic and nontraumatic causes of increased intracranial pressure are listed below. Much of our present knowledge of the physiologic reactions to increased intracranial pressure is based on the early observations of Harvey Cushing (9).

1. *Trauma,* i.e., head injury involving brain damage (concussion or laceration), with or without skull fracture, is frequently followed by increased intracranial pressure because of active bleeding (intracranial or extradural), because of subdural escape of cerebrospinal fluid, or because of cerebral edema which often follows trauma to brain tissue.

2. *Apoplexy* or spontaneous *intracranial hemorrhage* is an obvious cause of increased intracranial pressure. When a small vessel within the substance of the brain bleeds, the hemorrhage is not great and recovery of consciousness may be rapid. On the other hand, the outcome in severe cases is rapidly fatal.

3. *Infections,* i.e., meningitis (pyogenic, tuberculous, syphilitic), encephalitis, and tetanus may produce increased intracranial pressure by (*a*) inducing an edema of the brain tissue itself or by (*b*) obstructing the flow of cerebrospinal fluid by exudate or adhesions.

4. *Neoplasms* increase intracranial pressure by their actual growth within the rigid cranial cavity or by interfering with the flow of cerebrospinal fluid. When cerebral neoplasm is the cause of sudden unconsciousness, hemorrhage into the tumor is usually the primary factor in its production.

Clinical Manifestations. In head injuries, a history of trauma is usually obtained. Evidences thereof are lacerations and contusions of the scalp, crepitus or depressions of the skull itself (hematoma, however, may simulate a depressed fracture), bleeding from the ears or nose, or escape of cerebrospinal fluid. A roentgenogram may be necessary to detect fracture. Further examination is directed toward eliciting positive neurologic signs.

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depression (or hyperactivity such as delirium and convulsions) is produced by a disturbed cerebral physiology, as occurs in the psychiatric diseases, poisoning, uremia, etc. The classification is not exact, however, because the coma in uremia is sometimes due as much to an associated cerebral edema as to direct toxic injury to the brain itself, as shown by the occasional, though transient, improvement following lumbar puncture (Christian and O'Hare, 14). The wet, edematous brain is a well-known lesion in alcoholism; in very acute cases, lumbar puncture has also been used therapeutically (Williams, 15).

Diagnosis and treatment are urgent, of course, in patients who have ingested poison or are suffering from carbon monoxide poisoning. In the former case gastric lavage is instituted at once to rid the stomach of as much of the poison as possible. A large tube is necessary in order to effect rapid evacuation and to allow the use of large volumes of fluid; this cannot be done efficiently with a small tube. In carbon monoxide poisoning, artificial respiration with a gas containing a high percentage of oxygen and also carbon dioxide is indicated. The former is necessary because of the need to replace CO from the hemoglobin molecule as rapidly as possible, so that gaseous metabolism can occur normally. Carbon dioxide acts as a respiratory stimulus which also aids in overcoming the deficiency in oxyhemoglobin in these cases. The treatment of asphyxia has already been described. If a laryngeal obstruction is present, intubation or tracheotomy is lifesaving. Comatose patients are particularly liable to asphyxia due to relaxation of their pharyngeal muscles and obstruction due to the tongue falling back over the larynx; aspiration of vomitus is likely for the same reason. The prone position is therefore safer in comatose patients, or care must be exerted to pull the tongue forward and to apply suction to the throat. In diabetics, the prompt use of insulin and intravenous alkali (in the form of sodium lactate and Ringer's solution with or without glucose) may be lifesaving in the most severe cases. On the other hand, in hypoglycemia, intravenous glucose is specific. Severe dehydration and electrolyte deficiency require the adequate administration of fluids (containing the appropriate electrolytes) parenterally, which will relieve the symptoms rapidly.

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Depth of coma is determined by noting the *effect of stimuli of varying intensity.* The circulation is observed at intervals for, although unchanged at the onset of the injury, it may undergo alterations which are frequently diagnostic of a steadily increasing intracranial pressure. Thus, a *slowly bleeding middle* meningeal artery produces an extradural hematoma that increases the intracranial pressure progressively. The resulting cerebral anemia stimulates a reflex increase in the general blood pressure designed presumably to force more blood into the anemic brain. However, this leads to further extradural bleeding. As the general blood pressure rises, the pulse rate falls and may become slow (40 to the minute). Such an increase in blood pressure apparently occurs only from localized *arterial bleeding of this type.* Another sign of middle meningeal hemorrhage is the so-called "lucid interval." This period represents a temporary restoration of consciousness occurring between the initial unconsciousness, due to the accident, and that produced by the slowly forming hematoma. *Eventually, the circulation fails and death* ensues unless operation relieves the situation.

Lumbar puncture in the presence of increased intracranial pressure is condemned by many surgeons because of the danger of medullary compression at the foramen magnum. It is, nevertheless, widely used in trau*matic cases and serves a diagnostic purpose* by revealing the presence of bloody fluid. This may be of medicolegal importance when the x-ray of the skull is negative. It also serves to decrease intracranial pressure. The authors, however, do not recommend lumbar puncture as a routine procedure. Its danger can be lessened or eliminated by using a manometer and avoiding the loss of cerebrospinal fluid.

The relation of skull fracture to intracranial injury is an inconstant one, i.e., fracture may be present without evidence of brain damage, or it may be absent with serious injury to the cerebrum (10). A demonstrable skull fracture is of great importance medicolegally. The *various aspects of intracranial* injury are discussed under skull fractures in Chapter 27.

Frequently comatose patients with meningitis of one kind or another are brought into an emergency receiving room. There may be an elevation of temperature and leukocytosis to suggest the presence of infection, and a rigid neck or positive Kernig's sign to point to meningeal irritation. A lumbar puncture usually reveals abnormal fluid. The eyegrounds may show a swelling of the disks.

In such slowly increasing intracranial pressure as occurs typically in brain tumor, three cardinal symptoms occur, i.e., headache, *vomiting, and choked disk.* Convulsions may occur. Localizing symptoms of neurological nature depend on the location and type of tumor; a discussion of them belongs to special works on brain tumors (Pilcher, 11 and Davis, 12).

Treatment. In general, therapy is directed *toward the cause of the brain injury* or of the increased pressure. In traumatic cases, the detection of middle meningeal hemorrhage demands immediate craniotomy in order to evacuate the clot and ligate the artery. When a depressed fracture is present, operation is also indicated, but rarely is a decompression advisable. *Usually, however, the* treatment is conservative and is directed toward reduction of the intracranial pressure by intravenous hypertonic saline or glucose and lumbar puncture. Morphine is not to be given since it masks cerebral symptoms and depresses respiration. If persistent convulsions or hy*peractivity are too intense,* chloral hydrate, paraldehyde, or sodium amytal are given. Wechsler (13) has reported *that severe* convulsions which fail to respond by other means will often cease following the intravenous injection of 1 ml. of paraldehyde. If lumbar puncture reveals cloudy fluid, the patient is presumably suffering from a pyogenic meningococcus meningitis and appropriate anti*biotics are given,* even before the organism is identified. In other infections, the treat*ment is nonspecific. Apoplexy* is treated symptomatically; the increased intracranial pressure, though difficult to control, requires no special treatment. In brain tumor the treatment is neurosurgical.

PHYSIOCHEMICAL COMA

The diseases in this heterogeneous group have in common the fact that the sensorial

infections around important structures with disastrous results. Most important in deciding if primary tendon repair should be attempted is the length of time since injury. Although the antibiotics have possibly prolonged the time factor, four to six hours (10) is now considered the limit for primary tendon repair. This limit might be overstepped somewhat, depending on the wound and the circumstances under which it was received. If in doubt, it is much better judgment merely to close the skin and delay repair until a later time. A sharp lacerated wound sustained under favorable conditions, such as in the home, heals readily and is quite different, for example, from a crush injury. A crush wound causes damage over a wide area, blood vessels are thrombosed and tissues have such reduced healing powers they can scarcely survive. Badly torn and crushed skin flaps rarely survive. Under such circumstances it is much better judgment to delay definitive repair of deeper structures.

General anesthesia is needed for all except trivial injuries because (*a*) the patient does not tolerate long the constriction of the pneumatic cuff and (*b*) procaine infiltration of the hand, where there is little areolar tissue, impairs healing and decreases resistance to infection. A bloodless operative field is essential in order to see clearly and identify small structures. This is obtained by applying a blood pressure cuff to the upper arm, elevating the arm for two minutes to allow venous blood to empty, and inflating the cuff to 280 mm. of mercury. The cuff should be applied loosely so as not to obstruct venous return when the arm is elevated.

Careful attention to surgical technic will decrease scarring. Simply to know how to make incisions, repair tendon, and obtain hemostasis is not sufficient. Each structure must not only be accurately identified but handled with the greatest gentleness. The wound is kept moist by frequent saline irrigations and the finest instruments used. Blood vessels are ligated with fine sutures, care being taken to include only the blood vessel itself and none of the surrounding tissue.

Injuries to the Covering Tissue. Except for certain special considerations, the treatment of simple lacerations of the hand is the same as that applied to open wounds elsewhere (Ch. 14). Exclusion of tendon and nerve injury is necessary first by careful examination of function. There should be no probing or picking at the wound; the diagnosis is made entirely by examination of function. The size of the wound has no relation to its gravity; it is possible to divide all the structures on the dorsum of the wrist through a 2-cm. stab wound. At the time of initial examination, the wound is appraised as to the need for skin grafts or flaps because, if covering tissue is inadequate, repair of deeper structures may be contraindicated.

Tendon division can occasionally be diagnosed by noting the posture of the fingers on the arm board; e.g., division of one or more flexor tendons in a finger allows it to fall into extension; division of an extensor tendon allows the proximal phalanx to drop into flexion. Mechanical cleansing with soap and water is the most effective method of decreasing contamination, the importance of antiseptics being greatly overemphasized. A sterile dressing is put over the wound, the forearm and hand shaved and fingernails cut short. After washing the surrounding skin, the dressing is removed and the wound cleansed with a second sterile setup.

The principle of block débridement, i.e., excision of the entire wound to render it free of bacterial contaminants is not only unnecessary in the hand but impossible to perform (9). Furthermore, it is important that no tissue be sacrificed, especially skin unless it is devitalized. Proper débridement is accomplished by cutting away all tissue which has been deprived of its blood supply. Dead space is obliterated by carefully placed sutures and the skin is closed without tension. The application of a pressure dressing of fluffed gauze and immobilization of the hand on a splint are of great importance in promoting healing.

Avulsions. Tangential wounds of the hand may avulse a portion of the skin and result in a long flap, the distal part of which may be nonviable. This is especially likely if the base of the flap is located distally, a so-called retrograde flap. When there has been actual loss of tissue, the scarcity of subcutaneous tissue in the hand prevents skin approximation without undue tension on the

17

THE HAND

WILLIAM REQUARTH

Surgery of the hand is discussed in a separate chapter for several reasons. 1. Fingers and hands are more prone to injury because their prehensile function places them constantly in contact with the outside world, particularly in individuals doing manual labor. Even slight injury is often sufficient to introduce an invading organism that may already be present in the folds and crevices of the skin. 2. The manifold and delicate functions of motion in the hand, so essential in many kinds of manual activity, are particularly impaired by injury and infection which may produce serious and even permanent disability. The reasons are many; an important one is the poor blood supply to the fingers, as they are composed mostly of tendons, nerves, bone, and tough connective tissue. There is, therefore, little space for swelling, for increased blood flow, for exudation, and for leukocytic invasion, all of which are necessary in nature's response to injury. 3. There is a distressing tendency for infections to spread, not only by direct extension into neighboring spaces and tendon sheaths but particularly into lymphatics and into the general blood stream. Moreover, serious infection may follow hand injuries, even with the advent of chemotherapy. It is not surprising, therefore, that special study and care are essential, particularly since hand injuries and infections offer a tremendous challenge in that proper treatment can achieve a good final functional result, whereas ill-advised treatment, which is unfortunately too common, may be ineffective and even harmful.

There are a number of monographs devoted to this field to which the reader is referred (1, 2, 3, 4). The experiences with hand surgery in World War II also was extensive and contained many details of value in civilian surgery (5).

INJURIES OF THE HAND

The disability following even trivial wounds of the hand is considerable and may cripple the hand, resulting in an economic loss to the individual far out of proportion to the severity of the injury. Good functional results are best obtained by accurate anatomic repair at the time of injury; results of secondary repair weeks later being much less satisfactory. Wounds have been discussed in detail elsewhere (Ch. 14). Many of these factors apply to hand injuries, but there is sufficient difference and the initial care of the wound of such importance that the care of the injured hand demands separate consideration.

General Principles in Treatment. There are general principles in the treatment of the injured hand which must be closely observed if satisfactory results are to be obtained (6, 7, 8, 9). The details of treatment vary considerably among different surgeons and will not be considered (10, 11, 12). Scar and fibrosis are the greatest deterrents to a good functional result and all the factors which produce them—as hemorrhage, dead tissue, and damage due to rough operative technic—must be carefully avoided. Perhaps the most important cause of scarring is postoperative infection. For this reason, primary healing is an absolute essential for satisfactory end results. The lack of loose areolar tissue in the hand confines even low-grade

sutures, yet *the wound must always be closed.* Raw areas left open become covered with granulation tissue and require weeks to heal. During this extended period of nonuse, loss of function may result; constantly exposed tendons usually become necrotic and are extruded. For these reasons, when caring for the injured hand it is extremely important that the surgeon always close the wound, if not by simple suture, by a skin graft or local flap. Although as much skin as possible should be saved, it is a serious surgical error to replace a flap of skin which may not be viable. Such flaps seldom survive, quickly become necrotic, and must eventually be excised, thus delaying the whole process of healing. Under circumstances when the viability of the skin is in doubt, it is better judgment to excise it and cover the wound with a skin graft.

A free skin graft (one not attached by a pedicle) is suitable for covering a raw area. The best graft for use in surgery of trauma is the intermediate-thickness or razor graft (13, 14, 15) (Fig. 1). It can be cut easily from the volar surface of the forearm or the medial aspect of the thigh with a Blair knife (16), dermatome, or even a small, straight razor. It is important that the graft be only part-thickness although this can be varied. The thick-split (17) graft resists injury better and has a more normal appearance than the thinner graft; however, with this graft it is more difficult to get a good "take." If the surface is clean and the blood supply good the graft may be thick; poor blood supply and the possibility of infection require the use of a thinner graft even though the eventual cosmetic result may not be as good. Intermediate-thickness grafts will close the wound and give primary healing, and if further reconstructive surgery is necessary, it can be planned at a later date. The important point is not to leave the wound open. Free grafts of full-thickness skin should not be used unless one is skilled in their use.

A pedicle flap of skin and subcutaneous tissue is used where bone, raw tendon, or nerve is exposed, since a free graft grows poorly on such a surface. Occasionally, adjacent skin can be used as a *rotation flap* (Fig. 2) especially on the dorsum of the





Fig. 2. Partial amputation of thumb closed with local rotation flap. Caught hand in power mower, resulting in tangential amputation of thumb and division of both flexor tendons to index finger.

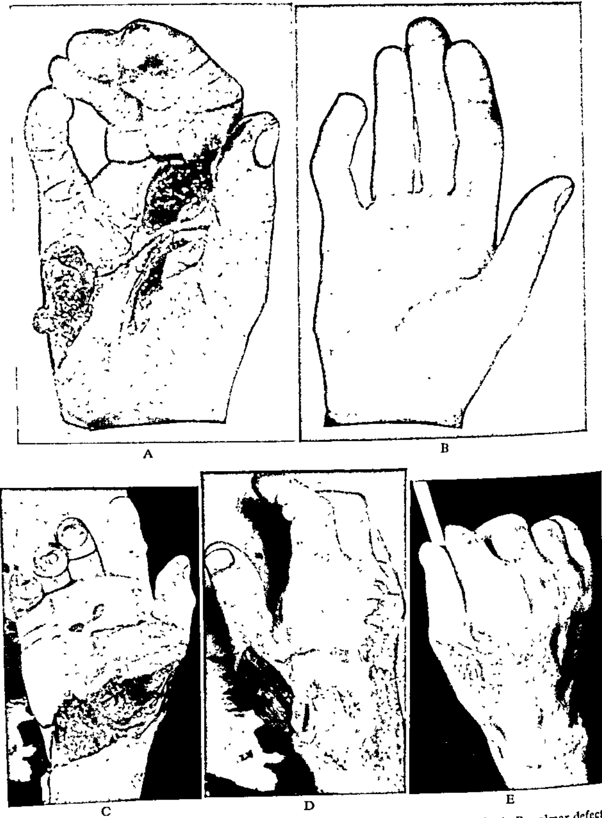


Fig. 1. Traumatic skin defects of hand repaired with intermediate thickness graft. A, B, palmar defect result of planing machine injury. C, D, E, skin loss after corn picker injury. The skin on the dorsum was intact but not viable and therefore excised and replaced with a free graft.

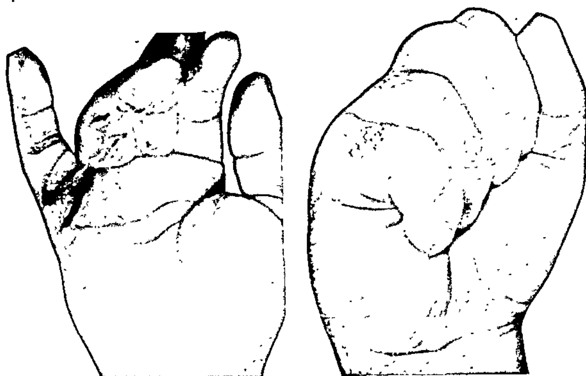


Fig. 4. Division of both flexor tendons by knife wound. Injury occurred with hand in closed position; the proximal tendon was easily retrieved without need of an additional incision.

langeal joint is possible through the action of the lumbrical and interosseous muscles.

The position of the divided tendon ends may often be predicted. If divided at or distal to the metacarpophalangeal joint with the fist clenched, the distal portion of the tendon is short and far distal but the proximal fragment is long and easily retrieved (Fig. 4). If the injury occurs with the fingers extended, the distal portion is long, the proximal fragment of the tendon is short and may retract as far as the carpal tunnel or even the wrist (Fig. 5). Determination of the position of the tendon ends prior to operation aids in the planning of incisions.

Adequate surgical exposure of the divided tendon is rarely possible through the laceration itself. The laceration should be enlarged from each end; e.g., extending a transverse laceration of the finger proximally and distally along the ulnar and radial aspects of the finger just dorsal to the flexion creases. When possible, the incision should be planned so that a flap of skin and subcutaneous tissues is formed which will cover the line of suture. Incisions should never cross flexion creases nor be placed down the mid-line of the finger because of the danger of contracture.

If both flexor tendons are divided in the digital sheath, it is advisable to excise the sublimis as far distally and proximally as possible and *repair only the profundus* since satisfactory function is possible through the action of this tendon alone. Repair of both tendons when divided in the digital sheath usually results in adhesions between the tendons and a poor result. Function after repair of flexor tendons divided at the level of the middle or proximal phalanx is often unsatisfactory even when expertly done; the prognosis for return of function improves as the level of division moves proximally, e.g., to the palm or wrist.

There are many variations in the technic of suturing tendons, but fine silk or wire is the suture of choice (Fig. 6). Knots should not be allowed to interpose between tendon ends, and the finest caliber of suture material that will maintain opposition should be used. When several adjacent tendons are involved, care must be exercised in identifying the ten-

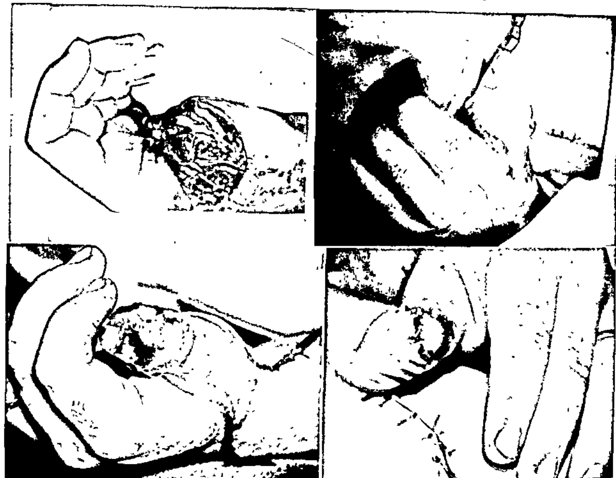


Fig. 3. Skin defects repaired with abdominal pedicle flap where bone and tendon exposed. Above, amputation of thumb by corn picker. Flap is raised and transferred in one operation, detached after 14 days. Below, avulsion of soft tissue of thumb in grinder. It is important to preserve length of thumb whenever possible.

hand. When skin and subcutaneous tissue are needed and a local flap cannot be devised, it is then best to raise and transfer an abdominal pedicle flap (13, 18, 19) (Fig. 3).

Injuries to Tendons. Tendon repair should be undertaken immediately in all cases when conditions are favorable, but there are several distinct contraindications to primary tendon repair. It has been noted that repair undertaken beyond the time limit of six hours after injury is hazardous because of the possibility of infection. Tendons should not be repaired in wounds contaminated by tooth injuries and others inoculated by bacteria. Crush injuries are unsuitable for tendon repair as are wounds which have received meddlesome first aid and sent in for operation later. There must be adequate covering tissue and no skin defect present. Finally, the surgeon should understand the technic of tendon repair and have the proper facilities to undertake it. If conditions are not right for primary tendon repair it is much better judgment merely to close the skin and undertake secondary repair at a later time. Division of the flexor tendon in the digital sheath overlying the middle and proximal phalanges is followed by such poor results that primary repair here should be attempted only under the strictest conditions (20, 21).

Flexor Tendons. Deep flexor tendons and the flexor pollicis longus insert at the bases of the distal phalanges and their division causes inability to flex the distal phalanges when the middle phalanges are held in a fixed position. The flexor digitorum sublimis inserts at the base of each middle phalanx and flexes the proximal interphalangeal joints. However, even with both flexor tendons divided, flexion at the metacarpopha-

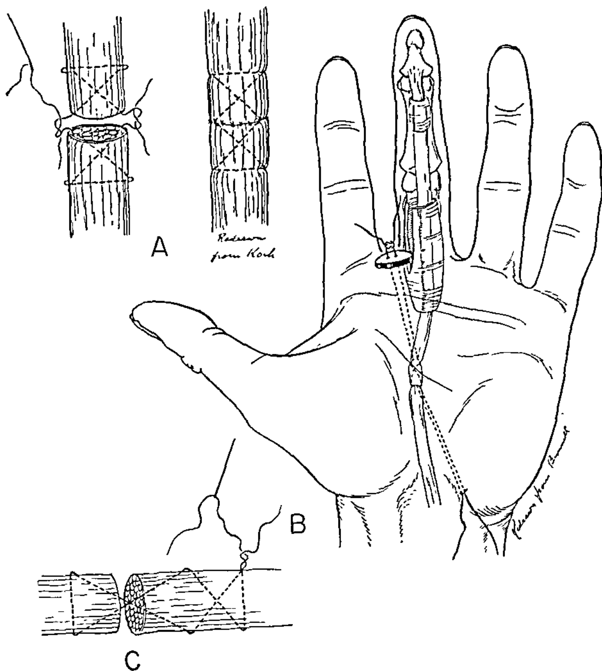


Fig. 6. Tendon suture. A, Mason-Allen suture; B, Bunnell pull-out wire; C, "core stitch."

dons and attaching the correct segment of the central to the correct segment of the distal end.

Soon after repair, the tendon ends soften so that sutures tend to pull out. Because the holding power of tendon for suture is low, heavy silk of high tensile strength is useless and actually harmful because of its irritating quality. It is much more important to use fine sutures and to keep the wrist and metacarpophalangeal joints flexed on a splint to prevent tension on the suture line. A fibrinous cuff forms at the site of healing and, after the second week, fibers grow from one tendon to the other to form a strong union (22, 23). During this time if motion is allowed, the tendon is irritated by stretching and tends to enlarge and become ovoid in shape. Therefore early

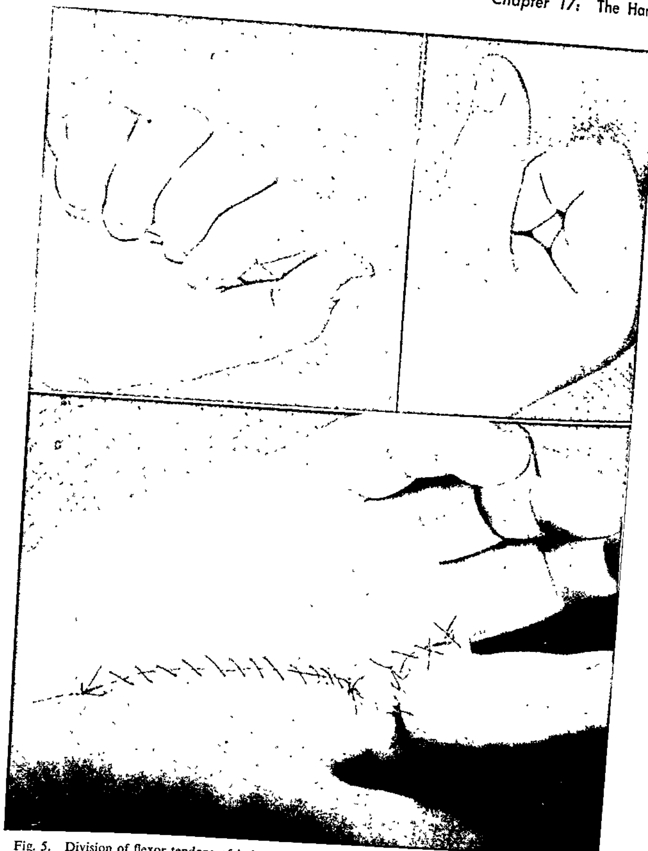


Fig. 5. Division of flexor tendons of index finger with glass. Injury received with finger in extension, resulting in short proximal tendon. Note supplemental incision made proximally to retrieve retracted tendon end.

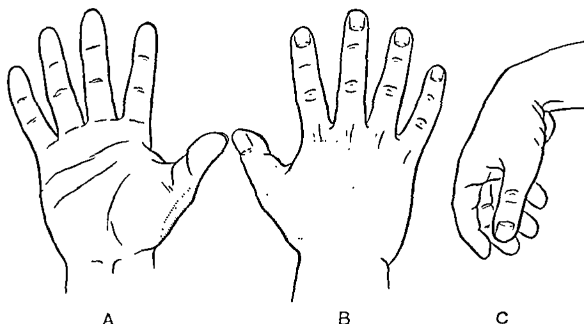


Fig. 8. Sensory and motor findings in radial nerve paralysis. A, sensory changes on the palmar surfac B, sensory changes on the dorsal surface; C, wrist drop due to motor paralysis.

wire to prevent retraction. Secondary suture is deferred until a later time.

Division of the *radial nerve* at the elbow or higher causes wrist drop plus inability to extend and abduct the phalanges of the thumb. There is occasionally temporary sensory impairment in an area between the first and second metacarpals (Fig. 8). Division of the posterior interosseous branch of the radial nerve results in inability to extend the fingers and thumb but the wrist extends to a neutral position through the action of the extensor carpi radialis longus. The posterior interosseous nerve is often damaged during surgery in the region of the head of the radius.

Division of the *median nerve* in the lower forearm or wrist produces anesthesia of the radial part of the palm, the thumb, the index and middle fingers, and the medial half of the ring finger (Fig. 9). Paralysis of the thenar muscles prevents opposition of the thumb to the base of the little finger (Fig. 10). In old, untreated median nerve paralysis, the skin is shiny and atrophic, the thenar eminence flattened, and the thumb pulled close to the hand by the unopposed adductors (Fi 11).

Division of the *ulnar nerve* at the wrist re sults in paralysis of all the interossei, the ac ductors of the thumb, and the two ulnar lum brical muscles. The patient is unable t

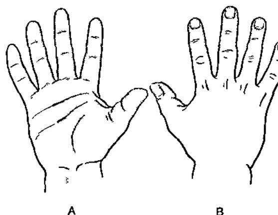


Fig. 9. Areas of anesthesia in median ner paralysis.

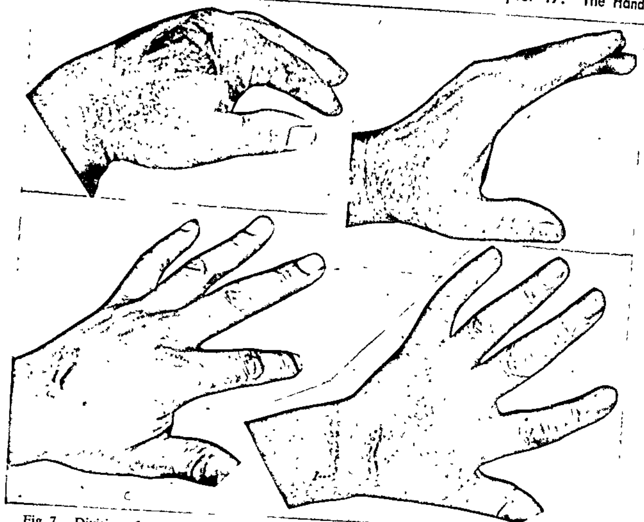


Fig. 7. Division of extensor tendons. Above, left and right, laceration on broken milk bottle. Extenso tendon is part of aponeurosis in distal part of dorsum of hand and minimal retraction of tendon end occurs. Below, left and right, injury by knife wound proximal to extensor aponeurosis. Maximun retraction occurs and supplemental incision (I) is necessary to retrieve tendon.

motion after tendon repair actually increases the chance for a poor result. Immobilization is continued for three weeks after which limited use is allowed and after five weeks the splint is removed.

EXTENSOR TENDONS. Extensor tendons are not enclosed in a sheath on the dorsum of the hand, being loosely attached to one another through areolar tissue and the dorsal aponeurosis. They retract very little and after repair gliding motion is easy to restore. Results are good and repair is not difficult (Fig. 7). Frequently an extensor tendon may heal spontaneously without suture if the finger and wrist is kept splinted in extension for several weeks. Because the extensor tendons do not communicate with any major space of the hand, infection following primary repair is never as serious as after flexor tendon repair. For these reasons, the indications for primary repair are more liberal. After repair, the metacarpophalangeal joints in the wrist are splinted in extension for five weeks.

Injuries to Nerves. The diagnosis of division of peripheral nerves is made by careful examination of disturbances in tactile sensation in the palm and fingers by means of a pin and a piece of cotton, and also by examination of the motor function of the small muscles of the hand. Immediate primary suture of nerve is usually possible, the conditions of time, degree of contamination, and amount of damage to surrounding tissues being more liberal than those for tendon. Under unfavorable conditions, the nerve endings may be drawn together with a single suture of fine

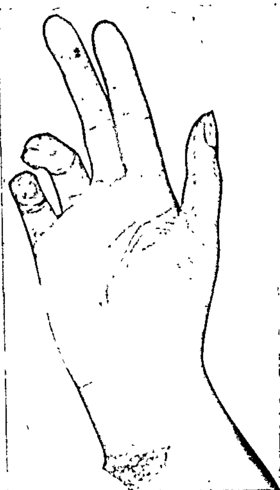
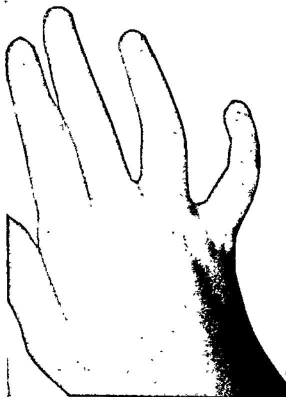


Fig. 13. Ulnar nerve paralysis. Left, knife wound of wrist with typical deformity of ring and little fingers. Right, paralysis after fracture of humerus. Recovery was spontaneous. Note hyperextension of proximal phalanges of ring and little fingers and flexion of distal.



prognosis following repair is poorest in such mixed nerves as the ulnar nerve, and is best in the radial, which is nearly all motor. The median occupies the middle ground, being mostly sensory with some motor fibers to the thenar region.

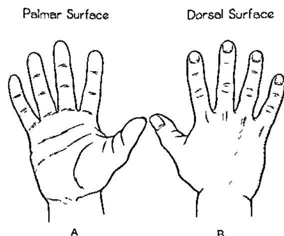


Fig. 14. Areas of anesthesia in ulnar nerve paralysis.

Return of sensation nearly always occurs after repair of the median and ulnar nerve whereas the outlook for return of motor function is much more uncertain. Other factors affect the result of nerve repair, e.g., the amount of scar tissue that forms between the nerve endings and the length of time that the paralysis has existed prior to repair. When the paralysis has existed for more than two years, the muscle atrophy and degeneration are pronounced and usually permanent. The time required for return of function after satisfactory surgical repair depends upon the distance from the point of suture to the actual nerve endings and may be a year or longer.

During World War II, the results of primary nerve repair were so unsatisfactory that

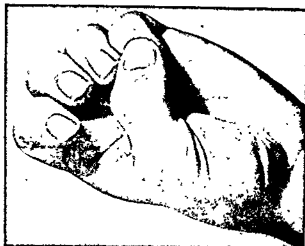


Fig. 10. Motor test for median nerve palsy. With fingers flexed and metacarpophalangeal joints held in extension, patient is asked to place thumb on nail of little finger. Thumb must rotate across palm because action of intact flexor pollicis longus can closely simulate opposition of thumb.

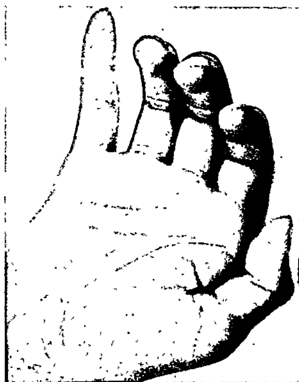


Fig. 11. Old median nerve paralysis. The paralyzed thenar muscles are atrophic, thenar eminence flattened and thumb pulled close to hand by unopposed adductors.



Fig. 12. Motor test for ulnar nerve palsy. Patient is asked to abduct index finger against examiner's forefinger. The first interosseous muscle (arrow) contracts if motor fibers are intact.

spread the fingers or adduct the thumb (Fig. 12). The classic deformity of ulnar paralysis is hyperextension of the metacarpophalangeal joints of the ring and little fingers and flexion of their proximal interphalangeal joints. Normally, the lumbrical and interosseous muscles flex the finger at the metacarpophalangeal joints and extend the distal phalanges. Because all of the interossei and the two ulnar lumbricals are paralyzed to these fingers, the unopposed common extensor extends the proximal phalanges and long flexor tendons flex the distal phalanges, producing the "claw hand" deformity (Fig. 13). There is sensory loss of the skin over the ulnar third of the palm and the ulnar half of the fourth finger and all of the fifth finger (Fig. 14).

Return of function after nerve repair depends upon the growth of the axons into the distal segment of nerve. In mixed nerves, i.e., sensory and motor, it is extremely important that the nerve ends be united without axial rotation because this results in motor axons growing into sensory axons, and vice versa. The chance of axial rotation is greatly decreased in fresh injuries, especially if the nerve has been divided tangentially or has a small blood vessel on its surface and the ends can be "matched." However, some degree of rotation always occurs and for this reason the

those of the first group are usually simple, the rest more complicated.

Chemotherapy, when used early, can greatly decrease the virulence of infection and eliminate many complications. However, the antibiotics have not eliminated the need for good surgical principles in the care of infection. As in other fields of surgery, the control of infection is based not only on accurate diagnosis but also upon identification of the organism. Antibiotics are most effective in bringing under control the acute spreading infections unless the infection is caused by an organism not sensitive to the antibiotic used. It is true that the antibiotics occasionally abort an infection in the early stages, e.g., a felon, but more often incision and drainage are necessary. Where localization has occurred, antibiotics have no effect except perhaps to help keep it localized.

1. SUPERFICIAL INFECTIONS. These infections of the hand are similar to those occurring elsewhere and are caused by puncture wounds or other injuries. Only the skin, or at most the subcutaneous tissue, is involved. Although arising outside such structures as the closed space, tendon sheaths, or fascial spaces, they have a tendency to extend or penetrate into them. It is important, therefore, here as well as in any hand infection to examine the structures repeatedly for extension of swelling or tenderness. Drainage of the pus by an incision sufficiently shallow to avoid tendon sheaths and nerves is often necessary.

Carbuncle of the hand is a term used to describe multiple abscesses of the furuncle type with a cellulitis affecting the dorsum of the hand. The infection is deeper, however, than in furunculosis. Adequate drainage, usually by cruciate incision, is usually indicated.

2. PARONYCHIA. This is a less serious type of infection located under the eponychium and about the root of the nail; hence its name paronychia. The infection is usually spontaneous although a history of injury of hangnail is sometimes obtained. The forerunner of the subungual abscess (paronychia) is the eponychia, a small bleb of pus alongside the nail with no subungual extension. If neglected, the pus spreads toward the opposite side and burrows beneath the nail to become a subungual abscess (Fig. 16). Because of its tendency to extend along the base of the nail to the other side it is often called a "run-around."

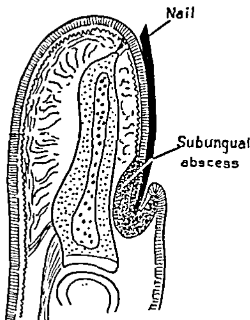


Fig. 16. Paronychia and subungual abscess. Longitudinal cross section of terminal phalanx showing the superficial location of the abscess beneath the cuticle, as well as the deeper (subungual) portion which is covered by the proximal part of the nail.

The treatment of any eponychia is to evacuate the bleb of pus and cut away part of the overlying skin to ensure drainage. It must be emphasized that this treatment will *not cure a subungual abscess, and to use it in* hope that more radical measures will not be necessary only prolongs the disability. A subungual abscess is suspected when an eponychia fails to heal or when pressure on the nail causes pus to exude. Adequate drainage of a subungual abscess is obtained only by complete removal of the proximal one third of the nail. Two parallel incisions are made extending proximally from the base of the nail, the flap thus formed is elevated, and the nail is removed. One should be certain that no nail fragments are left at the angles to act as foreign bodies and cause drainage. A piece of petrolatum gauze is laid under the flap for 24 hours and the finger immobilized on a simple tongue blade splint.

Suppuration occasionally persists despite

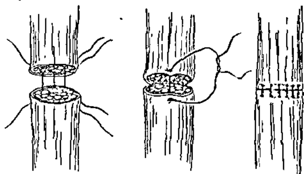


Fig. 15. Technic of nerve suture. (Redrawn from Koch.)

some advocated delayed secondary repair three to six weeks after injury (24, 25). It was thought that the poor results might be due to difficulty in approximating the freshly cut nerve ends and also that better axon penetration would result after the reaction of degeneration was completed. A controversy arose which is not yet settled (25). It would seem that immediate repair is preferable when possible; and, if secondary repair is necessary because of contamination or other factors, it should be done soon (26).

The nerve is sutured with interrupted fine sutures of No. 000000 black silk, being *careful to place the needle only through the perineurium* and to avoid trauma to the nerve *endings by rough handling.* As many as 12 to 16 interrupted sutures are inserted to obtain accurate approximation (Fig. 15). The wrist and hand are splinted for six weeks in a position which allows no tension on the suture line since the repair is for approximation alone and has little holding power.

If paralyzed muscles are allowed to be continuously overstretched by the action of unopposed antagonists, function is frequently poor even after regeneration of the divided nerve. Because nerve regeneration may require a year or longer, the patient should wear a splint during this period to support the paralyzed muscles in a position of physiologic rest. For example, radial nerve division requires a splint which will hold the wrist in dorsiflexion and the thumb extended and abducted from the hand.

ACUTE HAND INFECTIONS

Since many serious hand *infections begin* as trivial skin injuries which serve as a portal of entry for virulent bacteria, it should be *emphasized that* prompt and effective treatment of such lesions must be carried out in each case. Each scratch or break in the skin, no matter how small, should be immediately cleansed, a surface antiseptic applied, the lesion protected with a sterile dressing, and the part immobilized for a day or two (27). This simple treatment *will prevent a large percentage of the severe infections* and cannot be too strongly urged as a routine, particularly in shops and factories where such injuries are common.

Types of Infection. It is important to differentiate between acute spreading infections of the hand and localized collections of pus which are often the sequelae of the former. Spreading infections may follow simple abrasions with moderate swelling, redness, and surrounding cellulitis. The process may extend and red lines of lymphatic involvement may appear on the forearm and arm with enlarged and tender epitrochlear and axillary lymph nodes. Such an infection is still *spreading* through the tissues and responds best to chemotherapy and antibiotics. It is *important to avoid* premature incision and thus open fresh plains of tissue to the spread *of infection,* an error which can be fatal. Although delay in draining a localized infection *may permit destruction* of tissue with consequent severe disability, it is safer to await *unquestionable localization* rather than to risk incision into a spreading infection.

Of the various types of localized infections, perhaps the most serious are acute tenosynovitis *and palmar and* bursal infections, not only because they are more frequently associated *with septicemia* but also because the local manifestations are so intense. The *entire hand becomes swollen, stiff,* and immobile in a position of slight flexion. Extreme *disability frequently follows* such infections, even when the healing process is complete. *A septic hand is not infrequently* complicated by lymphangitis, lymphadenitis, and thrombophlebitis. *Other lesions may* occur as later complications; e.g., osteomyelitis, suppurative *arthritis, and gangrene.* In the following description of the various types of infection,

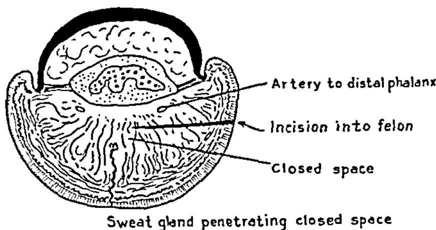


Fig. 19. The relation of the closed space to the bone and arteries supplying it. Transverse section showing also a sweat gland to illustrate one method by which the closed space may be invaded without apparent trauma. The proper method of incision into the closed space for the drainage of a felon is also indicated.

of an osteomyelitis must be taken for granted. Eventually, dead bone (sequestrum) separates and may have to be removed, but even then the end result is a deformed, sometimes painful, and often useless terminal phalanx.

Early incision into the closed space on one or both sides of the finger is urgently indicated (28). Chemotherapy should be used concomitantly, but rarely alone as the definitive therapy. The incision is never made through the pad of fat on the palmar surface, which is a specialized end organ containing a great concentration of sensory endings. Such an incision, while theoretically the most direct approach to the closed space, often produces hyperesthesia or actual pain in the healed scar because of cicatricial contraction of the many delicate nerve endings in the pad of fat. The proper incision is on the lateral aspect of the phalanx, carrying the knife inward and dividing the fibrous bands with a sweeping motion (Fig. 19). In order to avoid



Fig. 20. Web space infection between ring and little fingers. Left, abduction of involved finger is characteristic; *middle*, relatively minor infections cause marked edema of dorsum of hand; right, drainage by transverse incision in palm. (After Requarth in S. Clin. North America.)



Fig. 17. The connective tissue closed space. *Radiograph (redrawn from Dorrance) after injection of red lead to show the extent and location of this potential space.*

drainage. Prolonged drainage is most frequently the result of failure to remove the base of the nail. Occasionally, chronicity is due to a fungus infection, which is to be suspected when healing does not follow the therapeutic procedures just described. In such instances the use of fungicides may be helpful.

3. FELON. "Felon" (sometimes called whitlow) is a term which should be limited to an infection of the anterior closed space of the terminal phalanx, although it is loosely applied to any serious finger infection, especially when the bone is involved (Fig. 17). This "closed space" is located in the deeper portion of the pulp end of the finger and contains fatty tissue supported by numerous fibrous strands radiating from the periosteum of the bone to the periphery. It has no communication with the joint or tendon sheaths, although the flexor tendon inserts nearby at the base of the bone. Infection frequently develops spontaneously or whenever appropriate virulent organisms are introduced either by puncture of a sharp object, by direct extension from an overlying infection of the skin covering the finger pad, or by way of a *sweat gland.*

Exudation, one of the first manifestations of infection, distends this closed space within a few hours. Since there is little room for swelling, the tension becomes great and pain exquisite. The pain is of a throbbing character, made much worse with the hand in a dependent position. Tenderness is intense, but redness and swelling only slight (Fig. 18). Diagnosis and treatment, even at this early stage, is important lest the viability of the underlying bone be jeopardized by the increase of pressure within the closed space on the nutrient artery supplying it. At times, it is advisable to incise this space even though diagnosis is not definite, so important is early drainage. In the severe and neglected cases this may lead to a massive necrosis (osteomyelitis) of the entire phalangeal bone. This complication may not be detected objectively until radiologic changes occur, which take a week or two. Unless the pressure is relieved by early incision, the ultimate development

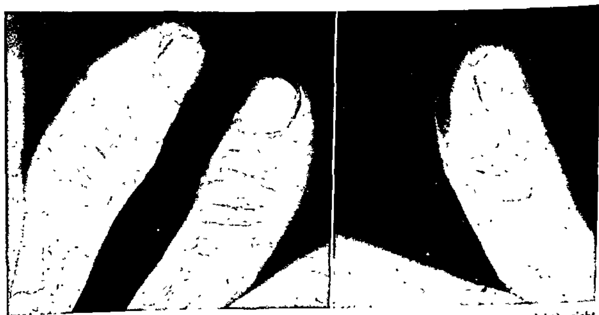


Fig. 18. Felon of left thumb. Left, swelling is scarcely perceptible (normal thumb on right); right, after incision and drainage. (After Requarth in S. Clin. North America)

and swollen and there is a hard, indurated mass in the web which holds adjacent fingers in extreme abduction. The abscess is drained through a transverse incision in the distal palm (Fig. 20).

5. ACUTE TENOSYNOVITIS. This infection is limited to the flexor tendon sheaths of the fingers and usually follows trauma, frequently of a very minor character. Moreover, it is not necessary that the injury penetrate the tendon sheath, since the infection may be carried to it by lymphatics or by direct extension through the sheath. It is a dangerous infection, because 1. it may lead to necrosis of the tendon with its resultant disability; and 2. it may spread directly along the sheath into the hand and forearm.

The flexor tendons lie in fibrous tunnels which bind them to the volar surface of the phalanges and prevent them from bowing outward during flexion of the finger. They are lined by synovial sheaths whose anatomical arrangement divides sheath infections into two groups. The sheaths of the index, middle, and ring fingers end in a blind pouch in the palm at a level of the metacarpophalangeal joints, a point which corresponds to the distal palmar flexion crease if projected into the palm. Pus tends to gravitate to this blind pouch, called the cul-de-sac, and may rupture into the thenar space if the index finger sheath is involved, or into the palmar space if the ring finger sheath is infected. The sheath of the middle finger usually ruptures into the palmar space but can also involve the thenar space.

The sheath of the flexor tendon of the thumb extends proximally to the wrist but enlarges in the palm to form the radial bursa (Fig. 21). The flexor tendon of the little finger likewise extends to the wrist and also enlarges in the palm, this portion being called the ulnar bursa and encloses the flexor tendons at the wrist. The two bursas usually communicate with one another so that it is possible for an infection in the distal part of the sheath of the little finger to extend to the sheath of the thumb. Pus under tension in these bursas will rupture into the retroflexor space, an area between the pronator quadratus and the flexor tendons, and from here may extend up the forearm.

Fortunately, acute suppurative tenosynovitis is relatively uncommon when compared with other hand infections. It is usually secondary to puncture wounds, tooth wounds, or neglected infections in the fingers. It seldom occurs after injuries, even though the sheath is opened and the wound later becomes infected.

Early diagnosis and treatment of infection of the tendon sheath is of prime importance in order to prevent necrosis of the tendon and extension, both of which usually occur in neglected cases (29). The demonstration of a wound of entrance may be helpful, but is not essential, for diagnosis. The classical symptoms are semiflexion of the involved finger, diffuse uniform swelling, tenderness along the sheath, and pain on extension (Fig. 22). There is moderate systemic reaction with elevation of temperature. The diagnosis is sometimes difficult and may be confused with subfascial infections of the digits. Almost any infection of the finger will cause pain on extension and care must be taken to immobilize the middle and proximal phalanges while extending the distal phalanx to avoid stretching the soft tissues. Tenderness along the sheath is particularly significant,

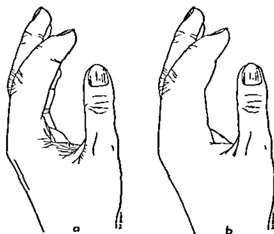


Fig. 22. Acute tenosynovitis of the index finger. a, early stage, showing merely the slight flexion and local swelling; this is the stage during which incision and drainage may be expected to result in complete return of function; b, later stage, showing extension of infection with suppuration and rupture outside the sheath. The tendon is probably necrotic at this stage and severe disability may result even if the infection is controlled.

entering the flexor tendon, which is inserted at the base of the phalanx, the knife should never reach the fold of the first joint. A similar incision may be made on the opposite side to ensure adequate drainage, but is not carried around the tip of the finger, the so-called "fish-mouth incision." This will produce a tender, sensitive scar. Chemotherapy, if started early, may obviate the need for operation.

4. Web-space Infection. The pus lies in the interdigital spaces of the web directly beneath the palmar fascia. The infection frequently begins as an infected callus, with a subcuticular abscess extending through the fascia to produce an abscess in the loose areolar tissue of the web. From here, the pus spreads quickly to the dorsal subcutaneous space. The web-space infection is also called a *collar-button abscess* because of the two pockets connected by a narrow channel.

The distal portion of the palm is tender

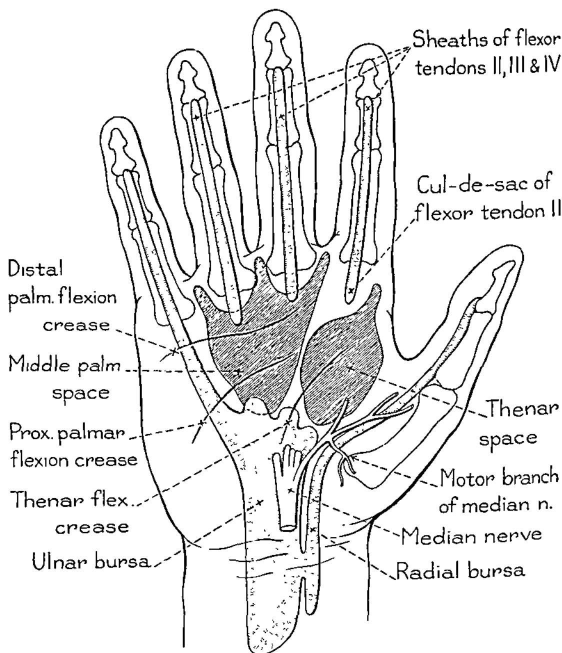


Fig. 21. The various spaces and tendon sheaths of the hand Note the relationship of the motor branch of the median nerve to the sheath of the flexor pollicis longus. (After Requarth in S. Clin. North America.)



Fig. 25. A neglected and inadequately treated case of acute tenosynovitis. The infection apparently ruptured into the subcutaneous tissue without extending into the fascial spaces; this abscess had been opened by a small incision. The necrotic tendon is visible. Healing was prolonged and resulted in a complete loss of flexion in the middle finger.

dle, and ring finger sheaths are opened through incisions placed along their lateral aspects. A second incision is always made transversely in the palm to drain the cul-de-sac. The incision for sheath infections of the thumb and little finger must avoid the motor branch of the median nerve, which lies directly in the path of the incision. The retroflexor space is always drained in radial and ulnar bursa infections, even though there is no evidence of pus in that region. This space is easily entered through a short incision just volar to the flat surface of the radius at the wrist (Fig. 24). A frequent complication of tenosynovitis is necrosis of the tendon with subsequent prolonged drainage (Fig. 25). Necrotic tendon acts as a foreign body the same as bone sequestrum and should be removed as soon as it is known to be necrotic.

6. Middle Palmar-Space Abscess. This space lies deep in the palm on the metacarpal bones and interosseous muscles, bounded on its radial aspect by the middle palmar septum, which extends from the center of the third metacarpal bone to the palmar aponeurosis, and on its ulnar side by the hypothenar muscles (Fig. 26). The flexor tendons of the third, fourth, and fifth fingers cover the palmar space. Distally, it is divided into many small compartments by multiple fibrous septa extending vertically downward from the palmar aponeurosis. Primary infection of the midpalmar space is rare except after a human bite wound of the dorsum which extends down the lumbrical canal into the palm. Neglected sheath infections of the third and fourth fingers occasionally rupture into this space.

Early, there are few signs except for tenderness in the palm and some pain on extention of the fingers. Later, the palmar concavity is obliterated and the palm assumes a thick, flat contour with marked edema of the dorsum. The palm is exquisitely tender with the fingers held semiflexed. Since the tendons of the middle, ring, and little fingers overlie the abscess, there is marked pain when these are extended.

The middle palmar space is drained through a transverse incision in the distal part of the palm parallel to the distal palmar flexion crease. The operation should be done in a bloodless field with care to avoid injury to the digital nerves and flexor tendons, which cross the line of incision at right angles.

7. Thenar-Space Abscess. The thenar space is separated from the middle palmar space by the same fibrous septum extending

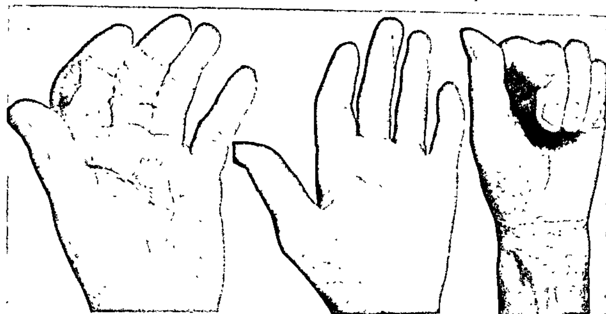


Fig. 23. Acute tenosynovitis of index finger. Left, five days after incision and drainage; middle and right, healed, showing degree of function lost. Emergency drainage of sheath infections is necessary to prevent loss of function.

especially in thumb and little finger infections. Slight redness may be present, but the infection *must not be mistaken for acute lymphangitis,* which, of course, requires nonoperative treatment, whereas acute tenosynovitis requires prompt incision.

Immediate drainage is imperative to avoid damage to tendon (Fig. 23). The index, mid-

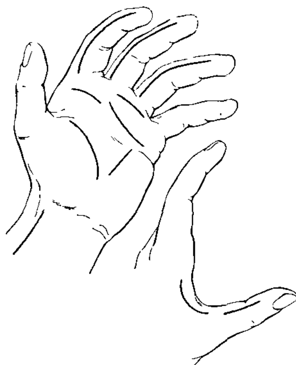


Fig. 24. Types of incisions for space infections of the hand. Lines of incisions for draining web space infections, sheath infections, middle palmar, thenar, and retroflexor spaces. Incisions must not cross flexion creases nor be in the mid-line. They must not damage important structures nor lead into uninfected areas. (After Requarth in S. Clin. North America.)



Fig. 27. A partly disabled hand resulting from extensive and multiple infections. The infection started with a bruise which the patient, a diabetic, opened *with a pin; an infection developed, which was lanced* three days later by her doctor. The thenar and mid-palmar spaces, as well as several dorsal abscesses had to be incised and drained before healing was complete. Present condition, one and a half years later, represents only a partial return of function.

(*b*) Tenosynovitis of the index finger is limited by the termination of the sheath, but ruptures (especially in neglected cases) readily *into the thenar space, which is in close relation* to the tendon sheath of the index finger.

(*c*) Tenosynovitis of the middle and ring fingers is likewise limited by the termination of the tendon sheaths, but ruptures readily *into the midpalmar space. Occasionally,* infection in the tendon sheath of the ring finger *may rupture into the ulnar bursa.*

(*d*) Tenosynovitis of the little finger extends readily into the ulnar bursa, and thence under the annular ligament into the forearm.

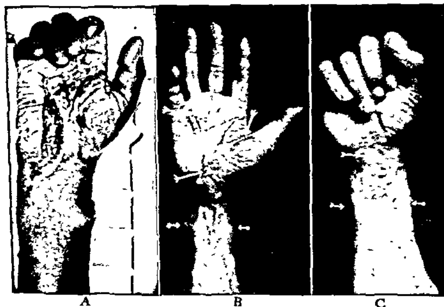


Fig. 28. Incision into the ulnar and radial bursa extending above the wrist. A, photograph *after incisions;* B, and C, results obtained two and a half months after treatment. (From Kanavel. Infections of the Hand, Lea & Febiger.)

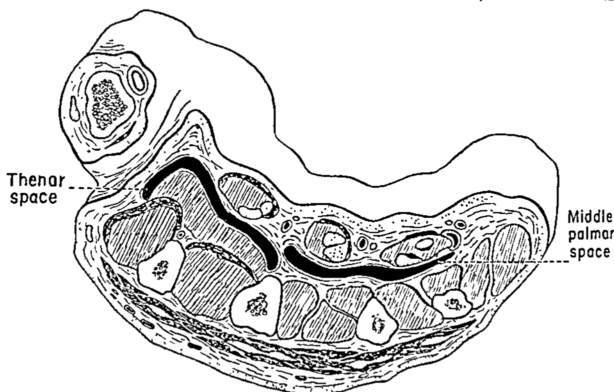


Fig. 26. Cross section through palm showing relationship of mid-palmar septum to palmar and thenar spaces.

from the middle metacarpal bone to the palmar fascia. It lies on the abductor pollicis muscle and is covered by the flexor tendon of the index finger. Thenar-space abscess is also rare. The chief sources of infection are puncture wounds of the radial portion of the palm or rupture of a neglected sheath infection of the index or middle finger.

The characteristic feature of thenar-space abscess is the balloonlike swelling of the thenar region, which holds the thumb in extreme abduction. The index finger is semiflexed and attempts to extend it cause pain. As in other major infections of the hand, there is marked edema of the dorsum. The diagnosis is not easy, because cellulitis in this region produces a similar picture although without abduction of the thumb.

Thenar space is best approached through an incision which parallels the edge of the thenar web. The first interosseous muscle is retracted and a forceps thrust through the fibers of the abductor pollicis muscle.

Infections of both the middle palmar and thenar spaces are now uncommon possibly because of chemotherapy. However, they may still occur when such therapy has been neglected or proves ineffective for reasons already discussed (Fig. 27).

8. Infections of the Radial and Ulnar Bursas. As already indicated, this type of infection is secondary to involvement of the tendon sheath of the thumb and little finger respectively, or of the palmar spaces. Though rarely involved primarily, it tends to spread rapidly up into the forearm and to produce necrosis of the flexor tendons. Diagnosis is helped by finding local tenderness and swelling. Flexion and extension of the respective digits will be limited sharply because of pain. Fever is quite constant as in fascial-space infection. Early incision is indicated (Fig. 28). Even if necrosis of the tendon is prevented by early incision, there may still be disability because of the adhesions between the tendon and its sheath.

Summary of Methods of Extension. The mode and direction of extension of infection in the various spaces of the hand may be summarized as follows (modified from Homans):

(*a*) Tenosynovitis of the thumb spreads readily to the radial bursa, and thence under the annular ligament into the forearm.

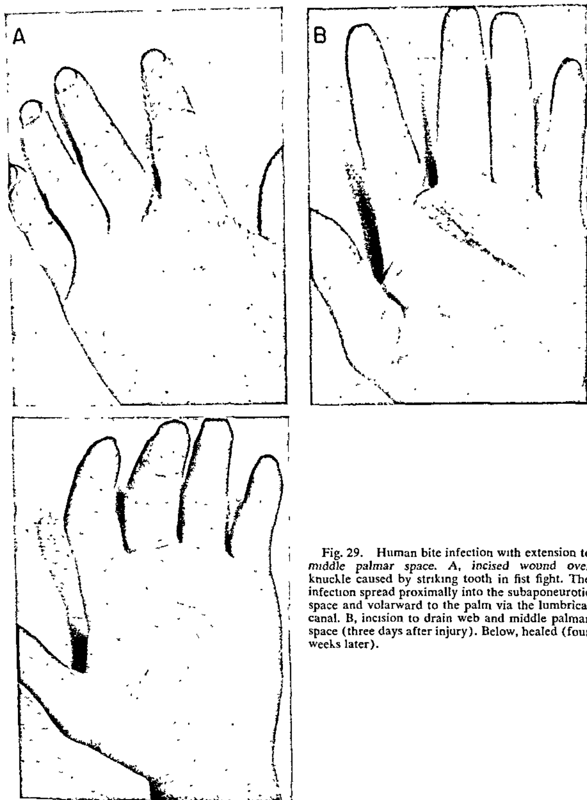


Fig. 29. Human bite infection with extension to *middle palmar space. A, incised wound over* knuckle caused by striking tooth in fist fight. The infection spread proximally into the subaponeurotic space and volarward to the palm via the lumbrical canal. B, incision to drain web and middle palmar space (three days after injury). Below, healed (four weeks later).

(*e*) An abscess in the thenar space may rupture into the radial bursa or midpalmar space; likewise, an abscess in the midpalmar space may rupture into the thenar space or ulnar bursa; *an abscess in the radial and ulnar* bursa may rupture into the thenar and midpalmar space respectively. Extension into the forearm under the annular ligament usually arises from the ulnar or radial bursas, but apparently may occasionally extend from the midpalmar space. In either case such extension should be detected when present.

Human Bite Infections of the Hand. These injuries deserve special mention because they present several unusual features. Experience has shown that wounds contaminated with human mouth organisms are very dangerous and produce the most destructive infections seen in the hand (30, 31). The functional disturbances which result are most serious *and often cannot be avoided in spite of careful* management. Although there is a wide variety of organisms in the mouth, the destructive part of the infection is caused by the spirochete and the fusiform bacillus growing in symbiosis under anaerobic conditions. They are not always demonstrable on smears and cultures but darkfield examination of a wet specimen will reveal their presence. The streptococcus, staphylococcus, and *E. coli* are often recovered from the wound. *Because of the bacterial flora of the human* mouth, these wounds are much more serious than the tooth wounds of an animal.

The majority of bite wounds occur over the knuckles, the result of a fist fight (Fig. 29). Penetrating wounds of the subcutaneous and subaponeurotic spaces are ideal for anaerobic infections, particularly those on the dorsum of the hand. With the fist clenched, a tooth wound over the metacarpophalangeal joint can easily injure the extensor tendon, open the joint, *and even damage the bone.* When the fingers are extended, the wound of entry glides proximalward with the aponeurosis and carries organisms into a closed area. Conditions are then ideal for anaerobic growth. The onset of a bite infection is usually rapid and within 24 hours the area is red and swollen. A grayish, watery, foul discharge appears first. Pain is prominent and aggravated by the slightest degree of motion; the temperature is elevated. Seemingly trivial wounds may be extremely serious. As the infection progresses, gangrene of the superficial tissues ensues and a large amount of *thick, putrid* pus exudes from the wound. Tenderness and pain in the palm indicate infection of the middle palmar space.

TREATMENT. The treatment consists in immediate cleansing with soap and water and immobilization on a splint. Under no circumstances should these wounds be closed, even though it is a temptation to suture what may *appear to be a clean laceration.*

After proper cleansing, the hand is put on a splint in the position of function and warm, moist dressings are applied. Massive doses of penicillin may abort the infection unless the metacarpophalangeal joint has been entered. In such cases suppurative arthritis, osteomyelitis, and ankylosis usually follow.

A most important phase of treatment is the detection of extension. At first, this occurs laterally in the soft, subcutaneous tissue of the dorsum but the pus soon moves *distally* along the side of the finger to the lumbrical canal and palm. The first sign of midpalmar-space infection is an indication for incision and drainage of this space. It is most important that this be done early to avoid destruction of the flexor tendons.

Operations on Hand Infections. Unlike the *simple operation for opening* furuncles or simple abscesses elsewhere, the surgical treatment of serious hand infections is often a procedure requiring the utmost of special judgment and skill. With the exception of paronychia and superficial abscesses, all hand infections must be treated with the greatest respect and care. Unless one is prepared to treat these patients adequately, it is far better to call in someone who can.

The decision as to the proper time for in*cision and drainage* is of great importance. Incision into an area of acute cellulitis or lymphangitis is a surgical error; on the other hand, early incision of a *felon or acute* tenosynovitis is essential for rapid and complete restoration of function. Diagnosis of the type and exact location of the infection *is* obviously a prime necessity. Frequent examinations may help, but the judgment and experience of the surgeon often spell the difference

3. *Gangrene* of the finger or entire hand is practically always due to special infections. Gas bacillus invasion is not the only one. Human bites, because they are symbiotic infections, may increase virulence to the point of producing gangrene.

4. The *disabled hand* is a term used to describe the stiff, atrophic, useless hand which follows severe or inadequately treated infections. It is particularly prone to develop after acute tenosynovitis and infections of the bursal and palmar spaces. The tremendous scarring with adhesions between the tendons, their sheaths, and adjacent tissues, is responsible in a large measure for the deformity and lack of mobility. To bring such a hand back to useful function presents a difficult therapeutic problem. Such disability can be prevented in a great measure by maintaining the hand in the position of function during immobilization. This seems a difficult lesson for physicians to learn, and the "claw hand" with metacarpophalangeal joints stiff in extension and phalanges pulled into flexion, is still a common sequela after infection or injury. Physiotherapy is helpful to a limited extent. The intelligent application of continuous traction splints will often correct deformities in a few weeks time (33). Most important is the attitude of the patient which must be one of willing cooperation and constant personal effort to increase the range of function.

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between a correct and an incorrect diagnosis and treatment. While chemotherapy may obviate the need for operation, as already mentioned, it may also complicate the decision as to its timing.

In operating upon hand infections a general anesthesia (gas or pentothal sodium) should be used. Blockage of the digital nerve at the base of the finger with large quantities of procaine and epinephrine or use of procaine in conjunction with a rubber-band tourniquet can cause gangrene of the digit (32). By using a general anesthesia all pain is avoided, and the surgeon may carefully make his incision, explore the abscess or space without haste, and make whatever counter or extended incisions are necessary.

Intelligent treatment requires an accurate knowledge of the anatomy of the hand. One must have consideration for the many small structures and understand their close anatomic relationships in order to place incisions exactly. The size and location of the incision or incisions depends on the type of infection. On the palmar surface of the hand, transverse incision along flexion creases should be used wherever possible(Fig. 24). Incisions must be sufficiently long to drain the abscess adequately. On the other hand, it is essential that extension of the infections by incising uninvolved structures or areas of active cellulitis be avoided. Counter incisions may occasionally be indicated, as in a felon, but through-and-through drains cause harmful pressure on nerves and tendons and should not be used. A drain is used to hold the skin apart in order that pus may escape; it should not be packed into the wound to act as a stopper. Drains are usually unnecessary after 48 hours and should not be reinserted. Finally, it should be re-emphasized that all surgery on *the upper extremity be done in a bloodless* field.

A perfect functional result cannot be achieved without good *postoperative care* which includes adequate chemotherapeutic coverage. Warm, moist sterile dressings are used for a few days only, because if used longer the skin becomes macerated and loses its resistance to bacterial invasion. After discontinuing moist dressings, the hand should be soaked twice daily in warm sterile water, dressed with dry gauze, and immobilized on a splint. Dressings should be changed with strict observance of asepsis, lest other contaminants be added to the already infected wound. Specifically, one should not use his fingers but handle dressings with forceps; a mask should cover the nose and mouth. Injured tissues must be immobilized to promote healing and decrease pain; proper splinting is therefore a major factor in successful treatment. The hand is splinted with the wrist slightly extended, thumb abducted, and the metacarpophalangeal joints flexed to 90 degrees (position of function). As soon as the infection subsides, active motion should be started and each joint put through a full range of motion once a day. During rehabilitation, much depends on the cooperation of the patient to increase active motion of the joints as soon as subsidence of pain permits.

Complications of Hand Infections. Lymphangitis, lymphadenitis, and septicemia frequently complicate infections of the hand as discussed earlier in this chapter. The other complications, perhaps less common but nevertheless serious, are as follows: osteomyelitis, arthritis, gangrene, and the disabled hand. Many of these complications are now relatively rare thanks to modern chemotherapy, especially when started early in the stage of invasion.

1. *Osteomyelitis* is generally due to neglected or inadequate treatment. Its development in a felon has already been described. It also occurs in the metacarpal bones after human bite and neglected space infections. Persistent swelling or drainage for more than two or three weeks suggests osteomyelitis which can be verified radiologically.

2. Suppurative *arthritis* is an infrequent complication unless a joint has been infected *primarily at the time of the injury*, as in human bite wounds. Diagnosis is not difficult because even the slightest movement of the joint causes exquisite pain. There may be a grating sensation elicited in the joint upon movement of the finger. There may also be abnormal mobility of the digit due to destruction of the supporting ligaments. Early incision is indicated to prevent, as much as possible, the destruction of tissue (especially the cartilage).

are dependent upon the degree to which the blood supply is impaired and upon the existence of certain types of infection, such as that produced by the gas bacillus. The following conditions are capable, either alone or in combination, of leading to such changes to the degree that amputation will be necessary.

Trauma. Extensive trauma may of itself result in destruction of so much tissue as to destroy the blood supply to the distal portion. However, when only a portion of the limb is severed, amputation should be withheld, particularly if the bone is not fractured. So often, extremities, which at first appeared doomed to gangrene, recover with loss perhaps of only toes or portions of them. Naturally, if infection develops, the indication for amputation is greatly increased. Fortunately, great strides in combating the infection have been made, and many limbs which might otherwise be sacrificed can now be saved. The measures which minimize the incidence of infection in wounds have been discussed in Chapter 14. Important ones are proper débridement, immobilization, antibiotic therapy, adequate irrigation, and zinc peroxide. Gas gangrene antitoxin is also used, but its value is uncertain. The incidence of gangrene (and amputation) of injury has also been sharply reduced by modern methods of arterial replacement (see Ch. 25). The incidence of amputation in war wounds involving the extremities is apt to be much higher than in injuries sustained in civil life, partly because of more severe trauma and the presence of foreign bodies (shell fragments, dirt, clothing, and so forth), but particularly because infection is much more likely, due to the fact that many hours frequently elapse between injury and therapy. For details of amputations under war conditions see Chapter 42.

Arteriosclerosis. Amputation performed because of arteriosclerotic gangrene is comparatively frequent and generally is limited to patients in the latter decades of life. The gangrene may be extensive, involving the entire foot and part of the leg. Fortunately, it is usually of the dry type with a minimum amount of infection, thereby justifying delay in regard to the time of operation. Such delay is frequently advisable because spontaneous demarcation of the extent of gangrene usually occurs, with a consequent preservation of a maximum amount of tissue. On the other hand, conservative therapy is often inadvisable because of increased disability, expense of prolonged hospitalization, and particularly because of the danger of infection. When infection develops, immediate amputation may be indicated because infection is more difficult to control in ischemic tissue. In this disease also, the use of arterial grafts has, in some cases, changed the older concepts and indications for amputation.

Diabetic Gangrene. The gangrenous process occurring in diabetes is usually not very extensive but is directly secondary to occlusive arteriosclerotic changes which are so common in diabetes. The gangrene is usually associated with infection, thereby making amputation urgent. If the process is primarily of infectious origin with little or no gangrene, conservative therapy including incision and drainage will usually suffice. As discussed in Chapter 19, more effective antibiotics have allowed us to be much less radical with amputations in diabetics.

Buerger's Disease. Gangrene in Buerger's disease is relatively slight, usually limited to the tips of the toes, is superficial, and is not commonly associated with severe infection. For these reasons, amputation will rarely be necessary and usually need be no more extensive than removal of a toe or part of a finger.

Infection. Amputation for infection is most commonly indicated when produced by the *gas producing organisms.* When the gangrene is beyond the limits of local care, amputation will be urgent and should be performed high, particularly if there is evidence of arterial obstruction; under such circumstances, the operation should be of the guillotine type. Other measures are also used, as discussed later in this chapter. It should be emphasized, however, that with the aid of modern chemotherapy, amputations will rarely be necessary except in patients who have been badly neglected or, on occasions, when the blood supply is badly damaged by trauma or by one of the vascular diseases such as arteriosclerosis.

Other types of infections may act as indications for amputation but practically only when significant arterial obstruction is also

18

AMPUTATIONS

Indications for Amputation
The Extent of Amputation
Amputations in Children
Operative Considerations

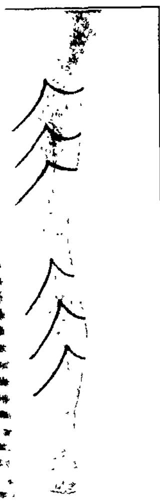
Decades ago, before the advent of asepsis, amputation was perhaps the most frequently performed operation; actually, it was performed in the majority of open fractures and massive soft tissue injuries of the extremities because such wounds were so often followed by septicemia and death. Unfortunately, the operation itself was also apt to be followed by the same train of events. An eminent writer in London about 1782 said that amputation "is an operation terrible to bear, horrid to see, and must leave the person on whom it has been performed in a mutilated, imperfect state." A surgeon who observed personally 46 amputations stated that of these, ten died, one of locked (sic) jaw, two of hemorrhage, four of hectic fever, and three from spreading gangrene. In 18, severe hemorrhage occurred and all suffered from violent "symptomatic" fever. Of those who survived many had painful stumps or wounds which failed to heal, probably because of osteomyelitis (1). The absence of anesthesia made the actual performance of the amputation a terrifying affair, and many are the weird tales of the slashing brutal methods incident to the operation. Time became the most important factor in the technic; the reputation of the surgeon depended almost entirely on the number of seconds he needed to dismember the affected limb. It was a shameful reputation for a surgeon to require as much as three or four minutes for the operation. The junior medical students of those days as they watched these performances were admonished by their serious classmates, "Don't blink your eyes, you will miss the operation."

This tradition of speed has unfortunately been handed down far too literally even to the present time. Many surgeons still use the time factor as a measuring rod of surgical excellence because they fail to realize that, in the average amputation at the present time, other factors are of equal or greater significance. Thus, far less harm is sustained by the patient if the procedure is done with proper care and respect for tissues than if performed in seven or eight minutes in a dramatic but needlessly traumatic fashion, necessitating mass ligatures and gross mauling of tissues. Needless to say, the operating time should be reduced to a minimum but not below a limit which will permit careful work. The blind worship of speed alone is an anachronism in the present century, and, when cultivated, deserves severe censure.

During the four year period of World War II, approximately 18,000 American service men lost limbs as a result of injuries. However, as Kessler (2) notes, "during the same period 120,000 American civilians lost limbs as a result of accidental injuries." This latter figure does not include amputations for arteriosclerotic gangrene and other vascular diseases which are increasing because of the gradually increasing life span.

INDICATIONS FOR AMPUTATION

In general, amputation is indicated 1. to save life (from the threat of infection and gangrene); 2. to combat incurable disability; and 3. to restore the individual to more useful activity despite the loss of limb (3). Based on specific surgical diseases, the two major factors determining the necessity of amputation



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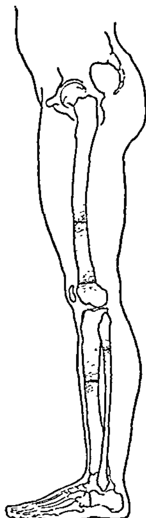


Fig. 2. The shaded areas of the bones represent preferential locations for amputation; the optimum level is indicated by the most dense shading.

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present. This point should be kept in mind, *lest amputations be performed needlessly* when incision and drainage together with other conservative measures will suffice. As already stated, any type of infection superimposed upon an existing gangrene may make amputation urgent. It is important to emphasize the necessity of making cultures (and especially stained smears) on all such lesions so that the etiologic organism or organisms may be identified and treatment varied accordingly. If a gas bacillus is found in the lesion before amputation, even with no clinical manifestations, the wound should be left wide open. If the material for bacterial examination is obtained for the first time at the operating table, the information may still be of great aid. Thus, even if a gas bacillus is first identified 24 to 48 hours after operation, the wound, if closed, should be opened widely, intensive chemotherapy instigated, and zinc peroxide applied; antitoxin may be advisable even though there is no proof that it is effective.

The mere presence of gas in the tissue is not at all proof that a gas bacillus infection is present; moreover, occasionally gas is produced by nonpathogenic organisms. In true gas gangrene with the proper use of antibiotics we are often able to excise certain muscle groups and avoid amputation.

Occasionally, amputation will be indicated for tuberculous or pyogenic osteomyelitis of the tarsal bones of the foot because either type rarely heals and usually is so painful as to be totally disabling.

Embolism. When an embolus lodges in a major accessible artery, the clot should be removed, with few exceptions, if the patient is seen within eight to ten hours after the embolism occurs. In late cases, or in unsuccessful embolectomy, amputation may be necessary. However, since infection is usually absent in these cases, amputation may be avoided by vein or artery grafts or delayed in order to wait for the development of a line of demarcation, thereby saving a maximum portion of the extremity. If the patient is young, delay is advisable because it permits the collateral circulation to reach its maximum. Not infrequently, the patient may then suffer only the loss of perhaps not more than a part of one or two digits, whereas the loss of a major part of the extremity might have seemed imminent earlier in the disease.

Of the major vessels to the extremities, obstruction of the common iliac and popliteal arteries is most apt to lead to gangrene. Embolism to the major arteries of the upper extremity results in such limited gangrene that amputation is rarely indicated, although embolectomy may be advisable to minimize the effects (see also Chapter 25).

Malignant Neoplasms. Sarcoma of bone is the most important neoplasm for which amputation is sometimes indicated, although there is considerable dispute as to whether amputation is advisable in certain types of bone tumors as discussed elsewhere. Occasionally, neglected squamous cell carcinomas (most common in the upper extremity) may invade so deeply that amputation is justified.

Deformity. Amputation is occasionally indicated for deformity, but usually only when function is completely lost and the deformed, useless member interferes with movement of the remainder of the extremity. For example, a severe injury or infection in a finger might result in a total loss of function. If the patient makes his living in a vocation or trade requiring deft movements of the fingers, the deformed finger might be a tremendous handicap in carrying out his duties; amputation of the deformed digit will frequently increase his efficiency. Injuries of the foot, with preservation of a part of the foot (for example, the Pirogoff and Chopart amputation) with or without deformity, may result in a painful or inefficient stump as far as function with a prosthesis is concerned; amputation at a higher level may be the procedure of choice in such instances. In all such cases, the decision is based largely on the need or possibility of reducing disability, rarely on cosmetic considerations.

Optimum Levels. The surgeon does not always have the opportunity of performing the amputation at the ideal level as a primary operation. This is particularly true in serious infections in very ill patients; in such a case, a guillotine type of amputation may be necessary followed later by a planned reamputation at a higher level when the infection has subsided. Likewise, in a seriously injured pa-



Fig. 1. Lines of Skin incisions for leg and thigh amputations. (Redrawn from Orr. Modern Methods of Amputations, C. V. Mosby.)

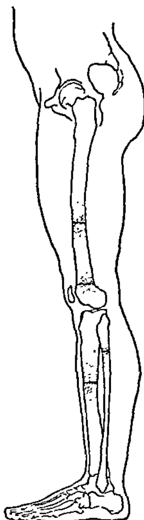


Fig. 2. The shaded areas of the bones represent preferential locations for amputation; the optimum level is indicated by the most dense shading.

tient, an emergency amputation may have to be performed through injured tissue, even though it is obvious that reamputation at a higher level will have to be performed later. With these exceptions, amputation should be carried out in practically all cases at optimum levels as discussed below.

In the *lower extremity* (Figs. 1, 2), amputations present entirely different problems from those in the arm. If the patient is to walk without crutches, an artificial limb of some type is obviously necessary. For this reason, close cooperation is essential between the artificial limb makers and surgeons. In general, two types of limbs are made. In one, the weight of the body is transmitted to the end of the stump, which thus may be called an end-weight-bearing stump. In the other type, a conical bucket is made into which the stump fits so that weight is transmitted largely to the sides of the stump and bony prominence. In amputations below the knee, weight is transmitted to the tibial tuberosities, tibial tubercle, and fibular head (Fig. 3A). In *above the knee* amputations, which are not end-weight-bearing, weight is transmitted to the ischial tuberosity (Fig. 3B and 4). The end-weight-bearing stumps, of which there are two, the Syme at the ankle and the Gritti-Stokes at the knee, are superior to other lower extremity stumps, and, when it is possible to produce either, it is the method of choice. They have greater durability than other stumps, and an individual with either of these

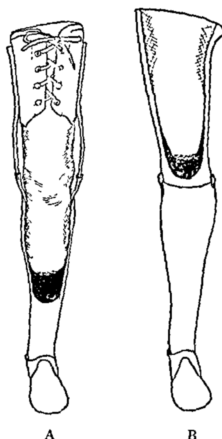


Fig. 3. Longitudinal section of the "buckets" of artificial limbs. A, weight-bearing on the sides of the leg stump. Occasionally it is necessary to remove the entire fibula before the limb can be worn with comfort; B, the soft tissues of the thigh serve admirably to sustain the weight of the body. Many artificial limbs are designed so that considerable weight is borne on the ischial spine but there is a growing tendency to have the weight borne entirely on the sides of the stump.



Fig. 4. Simplified type of amputation. Note absence (Courtesy, Hanger Artificial

stumps can acquire a gait superior to that possible with amputations at other sites.

Disarticulation through the knee is an excellent and nonshocking emergency open amputation when there is no chance of preserving the knee joint. It permits an excellent secondary revision. It is also an excellent type of definitive operation, as the bulbosity produced by the condyles and patella tends to stabilize the prosthesis and it is an end-weight-bearing durable stump (4). Its great disadvantage is the fact that few prosthesis makers will take the pains to properly fit it with an artificial leg.

Below the knee, the ideal length for a stump is 5 to 7 inches, depending on the height of the individual. The taller the individual, the nearer the stump length should approach 7 inches. Howe emphasized that a stump is preferable to a knee joi because, with skillful pros patient's own knee joint utilized even with such a chief advantages of this le that the stump can be fitt tients can learn to walk with One serious disadvantage tient cannot stand very long cause weight-bearing is limit tions at the *ankle*, the Sym above the articular cartilage c serving the flare of the tibia the lower ligamentous anchora to the tibia), being end-wei extremely serviceable. The Sy through the ankle may be unc woman from the cosmetic vie ankle portion of the prosthesis unsightly. In choosing the typ

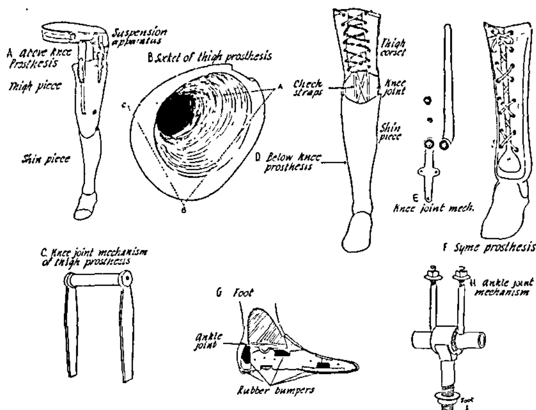


Fig. 5. Prostheses. A, above the knee prosthesis. B, socket for thigh stump. C, single axis knee joint. D, below the knee prosthesis. E, outside knee joint mechanism for below the knee prosthesis. G, foot. H, ankle joint mechanism. (Courtesy, F. M. McKeever.)

tion, the individual needs of the patient must obviously be considered. Amputation of toes or the distal portion of the phalanges will, of course, leave a serviceable stump and should produce very little disability. Of the amputations through the *foot*, the transmetatarsal (5) is the only satisfactory one. Any amputation in the foot proximal to the transmetatarsal area is not under balanced muscle control and often assumes a fixed deformity and develops painful callosities and bursae. The Pirogoff, Lisfranc, Sedillot, and many other eponymic amputations in the foot are only of historical interest and should not be used. If a balanced transmetatarsal amputation cannot be obtained, an individual is better off with a Syme amputation. In amputations above this level, the minimal length of the stump, for functional value in fitting the prosthesis, is 2.5 inches. Many of the mechanisms involved in the prosthesis for amputations in the lower extremity are illustrated in Fig. 5.

Amputations through the *arm* should leave a stump as long as possible, particularly in the upper portion. Although prostheses can be fitted to stumps only 2 or 3 inches long, they are of little functional value and are worn chiefly for cosmetic purposes, i.e., to fill out the shirt or coat sleeve. There is little difference, from the standpoint of efficiency of the stump, between an amputation just above the condyles and a disarticulation at the elbow. In the latter, the prosthesis can be held more securely with a minimum amount of apparatus, but the artificial joint will have to be put on the outside, making the limb more cumbersome.

In the *forearm*, the junction of lower and middle thirds has been considered the ideal site; however, with the development of newer prostheses which incorporate pronation and supination movements, it is wise to preserve as much as possible (Fig. 6). Some long forearm stumps will be cold and develop circulatory changes and ulceration. In the *hand*, as much length and tissue are preserved as pos-

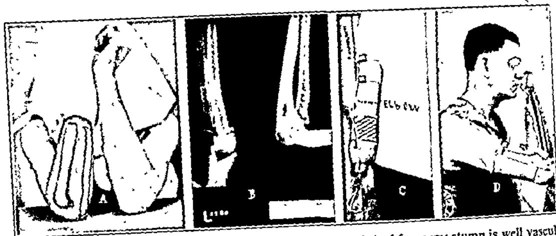


Fig. 6. Ideal forearm stump, junction of middle and lower third of forearm; stump is well vascularized and provides adequate lever for hard use of prosthesis. A, photograph. B, roentgenogram. C, prosthesis on stump. Socket does not encroach on anticubital space. D, prosthesis in full flexion. (From McKeever, J. Bone & Joint Surg.)

sible. One functioning finger is usually of more service than an artificial limb, although it is of course more desirable to have two fingers so that the function associated with opposition may be maintained. The thumb is usually the most important, since, even in the absence of all the other fingers, objects may be grasped between the thumb and stump of the hand.

THE EXTENT OF AMPUTATION

There is general agreement as to the optimum level for amputation in each segment of the upper and lower extremity as just described. Despite this, the decision must be made as to how much of the limb needs to be sacrificed; e.g., shall the lower extremity be removed at the thigh or leg? This problem is usually due to uncertainty as to the status of the blood supply to the lower leg and is complicated also by the presence of infection and gangrene. In certain specific cases (particularly in diabetic gangrene and infection), the amputation should be done through the thigh. In doubtful cases, valuable information as to the status of the circulation may be gained by first making exploratory incisions through the leg to determine the actual condition of the blood vessels and to determine the level of adequate blood supply. Numerous tests are available which serve the same purpose without exploratory incision. They may be described as follows.

Temperature of the Skin. A valuable, and one of the simplest tests of circulatory efficiency to the extremity is the determination of skin temperature, and particularly of a line of temperature demarcation. This may be done by thermocouple or thermometer, but the hand is fairly accurate in determining differences between warm and cool areas over the extremity. A thermocouple in a needle has the advantage of obtaining measurements of temperature deep within the muscle. Frequently the gradation from warm to cold will be abrupt, thus indicating sharply the site where serious arterial deficiency begins; usually it is fairly gradual. The borderline can usually be made sharper by exposing the patient's extremities for 15 or 20 minutes to room temperature and then covering them with warm blankets for a similar period. Upon exposure, the area with deficient blood supply will become quite cold and, when covered, will fail to become warm with the rest of the extremity. These features will be more noticeable by contrast if the circulation of the other extremity is reasonably normal. With few exceptions, the amputation should not be performed below the line of temperature demarcation.

Color. Changes in the normal color of the skin may be of considerable aid in determining the status of the circulation and thus the appropriate level of amputation. Although the skin of many patients is pale over the entire body, the area deficient in arterial supply will usually have a cadaveric pallor. Any

doubt about a true deficiency pallor can be cleared to some extent by pressing the patient's skin firmly with the examining finger tip. If the blood supply is efficient, the pallor produced by the pressure will be replaced by the normal color in two or three seconds; if the blood supply is deficient, the color may not return for many seconds. Upon elevation of the extremity, if arterial deficiency exists, the foot will become extremely pale and, upon dependency, will become red or purplish. If this deep blush extends very far above the foot, amputation below the knee will rarely be sufficient. The skin over the involved extremity is usually atrophic and shiny. *The Moskowicz test, based upon color* change following application of a rubber tourniquet, should not be carried out on arteriosclerotic patients because of the danger of injury to the sclerotic vessel walls.

State of Major Arteries. Many of the tests devised to aid in determination of the optimum level of amputation are concerned primarily with estimating the extent and efficiency of collateral vessels, since these may be more accurate in determining healing power than the presence or absence of pulsations of a major artery. It is, nevertheless, important to palpate for the dorsalis pedis and posterior tibial pulse; extensive gangrene will not be apt to develop if both pulses are present. The presence or absence of the two pulses would also be important in deciding upon the advisability of a conservative course of therapy in a diabetic infection with doubtful areas of early gangrene. The popliteal pulse is usually valuable in a negative way; e.g., amputation below the knee is seldom safe in the absence of a popliteal pulse. Additional data concerning the blood flow through the popliteal artery may be obtained by taking a blood pressure reading over the lower femoral region. Normally, it should be 15 or 20 mm. higher than the brachial pressure. If it is lower or no higher than the brachial, the circulation may be considered to be impaired and amputation below the knee inadequate. A roentgenogram of the leg will determine the amount of calcification in the wall of the major arteries and thereby furnish accessory data as to the vessels themselves. Additional roentgen studies immediately after the injection of diodrast into the vessel above the suspected lesion may reveal obstructive lesions and the condition of the arterial wall.

Histamine Flare Test. Suggested by Lewis, this test consists of the injection of 0.1 ml. of a 1:1000 solution of histamine in 0.5 per cent procaine intradermally at various levels on the extremity. With a normal circulation there will be a hyperemic flare surrounding the point of injection, constituting a positive reaction. A positive reaction indicates that primary healing of a skin flap should follow amputation at that level. A negative reaction, however, does not exclude the possibility that *healing will take place at that point.*

McClure–Aldrich Test. Intracutaneous injection of 0.2 ml. of 0.85 per cent saline at various levels may be of value. The wheal should disappear normally in 60 minutes; in the presence of abnormal circulation, particularly in the presence of edema, the wheal disappears more rapidly.

Freezing Test. To gain information regarding the circulation, Nyström (6) has suggested observing the reaction after freezing the skin by holding a cylinder of packed carbon dioxide snow on the skin for three seconds at various levels on the extremity. With a normal circulation, the area will thaw and become hyperemic in about two minutes. The blanching produced by pressure of the finger over the area returns to a hyperemic color in one or two seconds. If the arterial supply is inadequate, the return of the hyperemic color may be delayed 15 seconds or more.

Oscillometric Readings. Various types of oscillometers for recording the amount of pulsation (diffuse—not over the arterial trunk) at a given level are available. Many of them record very accurately the amount of pulsation at that point. By comparing these records with normal curves, an estimation of arterial damage may be made, except that it is not possible to ascertain the proportion of pulsation which is due to collateral flow. This latter feature constitutes the major criticism of the oscillometer, since the *number of collateral vessels and the rapidity of development of new ones are of vital importance in the indications for, and site of, amputation.*

AMPUTATIONS IN CHILDREN

Amputations are rarely required in children, but, occasionally, trauma and malignant tumors end in loss of a limb. Because these patients are growing, amputation requires special consideration and the utmost in careful judgment. For example, deformities may be sufficiently severe to justify amputation, yet operation should not be performed in early infancy because it will stop growth of the extremity, so vital to the fitting of a prosthesis later.

Certain principles of amputation in children may differ from those in adults (7). For example, amputation through the knee joint is greatly preferred to a supracondylar level in children, so that growth from the lower femoral epiphysis may be preserved. For the same reason, if at all possible, amputation should be performed through the malleoli of the lower leg rather than through the middle third. Under these two circumstances, the fitting of a prosthesis during childhood will be difficult, but, after growth is attained, reamputation can be performed and a good prosthesis fitted properly.

OPERATIVE CONSIDERATIONS

Immediate Preparation of Patient. Attention must first be directed to the presence of shock (especially after trauma), and treatment such as transfusions and intravenous saline or dextrose must be administered before amputation is performed. In badly crushed and contaminated extremities, tetanus and gas bacillus antitoxin, in doses at least double the usual prophylactic dose,* should be given, as well as prophylactic chemotherapy. In diabetic patients (see Ch. 19), acidosis should at least be corrected and the urine be made as nearly sugar-free as possible in the time available.

The night before operation (if this much time is available), the amputation site should be shaved and washed gently but thoroughly with soap and water and covered with a sterile towel. The next morning in the operating room, this cleansing should be repeated, and, after the skin is dried, the site should be prepared with iodine and alcohol or with cleansing detergents.

Anesthesia. Spinal anesthesia is satisfactory for many lower extremity amputations. If any degree of hypotension results, hemostasis is likely to be poor and postoperative hemorrhage of serious degree is likely to occur in the stump, unless the hypotension is corrected by vasoconstrictor drugs before closure to reveal bleeding. Spinal anesthesia should not be used in patients with impending shock from trauma. For amputation in the upper extremity, some type of inhalation agent (e.g., cyclopropane) is preferable. However, if a cardiac lesion exists, it may be desirable to use local anesthesia. A brachial block will be adequate for amputation through the forearm, but this requires skill and may fail. Local nerve block may be used for amputations of the toes or fingers but has the disadvantage of traumatizing tissue already having an impaired circulation.

Operative Principles. A *closed stump* has the advantages of rapid healing and good scar line and should be utilized when possible. Some surgeons prefer to close the wound around a small rubber tissue drain, but there is a growing tendency to either close the stump tightly or leave it entirely open.

The use of a tourniquet is highly desirable to obtain a bloodless field, but severe damage including nerve palsy may result with elastic rubber tubing. If there is room, a blood pressure cuff is much more desirable and less apt to injure nerves or blood vessels. In elderly people with arteriosclerosis, a rubber tubing type of tourniquet is actually unsafe. A tourniquet is poorly tolerated by the finger and should not be used, particularly since there is little need for it.

If it appears that a bilateral amputation will be required on the lower extremities, one knee should be preserved if possible because it is extremely difficult for the patient to learn to manipulate two artificial knee joints. Naturally, the surgeon should not allow this factor to influence his judgment when an amputation below the knee may be dangerous to life.

* The prophylactic dose of gas gangrene antitoxin contains 1,500 units tetanus antitoxin, 2,000 units perfringens antitoxin, and 2,000 units septicum antitoxin. However, there is not convincing evidence that gas gangrene antitoxin is very effective in prophylaxis. Large doses of penicillin may be more effective.

The *types of incisions* for the various sites may be summarized as follows: 1. long anterior and short posterior flaps for the thigh; 2. long posterior and short anterior flaps for the leg; 3. flaps of equal length for the forearm; 4. long palmar and short dorsal flaps for the hand and fingers; and 5. long plantar and short dorsal flaps for the foot and toes.

In general, the final skin flap should not be cut at the initial incision. Rather, the principle is followed of making large flaps which will eliminate the necessity of closing the skin with tension. Large flaps also lessen the danger of jeopardizing blood supply by undermining skin flaps if an error is made with the initial incision. Moreover it is always easy to cut redundant skin just before final closure. Since infection is so apt to develop in amputation stumps, the *utmost care and gentleness must be exercised in handling the tissues:* traction must be gentle, no mass ligation is permitted, and the minimum number of hemostatic forceps is applied.

Conservation of blood is extremely important since these patients are so often precarious surgical risks. The application of an Esmarch bandage from below upward would obviously conserve blood but is practically always *contraindicated* because of the tissue damage resulting therefrom. However, elevation of the limb before applying the tourniquet will result in conservation of considerable blood, particularly if a high thigh amputation is being done. Very frequently indeed, even the application of a tourniquet will be contraindicated because of the damage inflicted on arteriosclerotic vessels by the pressure of the tourniquet. In such cases, however, the need for a tourniquet will not be so acute.

There are numerous *points* in *technic* which can be applied to practically all amputations. The bone should be cut across far enough above the level of the skin so that the wound can be closed without tension. A circular incision through the periosteum is made around the bone, and the bone sawed through just distal to that line, thus minimizing splintering of the periosteum with subsequent spur formation. Removal of a cuff of periosteum from the end of the bone is not advisable (McKeever, 8). In amputation of the leg, it is essential that the fibula be cut off at least an inch shorter than the tibia. Because the fibula is commonly a source of discomfort in spite of proper care at operation, some surgeons prefer to remove it completely at the time of amputation, particularly in short stumps. It is not necessary in the function of the artificial limb. No muscle flaps should be interposed over the bone ends, although fascia may be used to cover the bone. During the dissection, care must be taken lest the various planes unnecessarily be separated from the skin, because of danger of destruction of blood supply to the skin with consequent gangrene and perhaps severe infection. Nerve trunks should be traced upward for a short distance so that, when cut, the end will be out of the wound; thus the danger of pressure on the neuroma at the stump end will be minimized. Injection of the nerve end with alcohol is not advised. Large nerves are ligated to prevent bleeding.

Individual Types of Operation. Detailed description of technic of the various amputations may be found elsewhere (8, 9, 10), however, the principles including their application and usefulness, will be discussed (see also Fig. 5).

Open Amputation. This is an extremely useful operation; because of its simplicity and rapidity of performance, it is often, indeed, a lifesaving procedure. It can be performed at any level on either the upper or lower extremity. It is particularly indicated when infection or edema is present in the limb, or when contamination in the crushed or injured portion of the limb is considerable. For this reason it is especially adaptable for military injuries in which closed amputation is contraindicated. Since it is assumed that another amputation will be necessary at a later date, the line of incision is made as far distal as feasible. However, it is surprising how often the stump heals so smoothly that a reamputation is unnecessary unless a shorter stump is desired. The term "guillotine" should be abandoned in favor of "open," since, as Kirk and McKeever (11) have emphasized, the cut stump should not be flat but concave. To achieve this, the skin is incised and allowed to retract before the fascia is incised. The superficial muscles are cut at a higher and

the deep muscles at a still higher level, thus permitting exposure of the bone so it can be transected at least several centimeters proximal to the skin incision. The periosteum is cleanly incised, but the bone is sawed across immediately distal to this level without removing a cuff of periosteum from the bone end; exposure of bone free from periosteum would encourage sequestration, since infection will develop in such a high percentage of cases for which this operation is chosen. The use of catgut is preferred to silk or cotton in an open amputation. No closing sutures are taken. Traction must be applied, by adhesive or other means, immediately after amputation to prevent retraction of the skin and soft tissues above the bone. The traction can be released to allow dressings as indicated. It must be maintained until the open wound has completely healed (12).

AMPUTATION THROUGH THE THIGH. When the amputation is performed in the middle third of the thigh or higher, an end-weight-bearing prosthesis cannot be used since most of the weight is borne by the ischium. The scar should be posterior and above the end of the bone. To achieve this location, a long anterior flap and a short posterior flap are cut. It is advisable to save as much stump as possible down to within a few inches of the knee. Therefore, the position of the scar can be ignored if more length can be obtained by some other incision. Up until recently, short amputations of the thigh could not be fitted with efficient artificial limbs, but, since the introduction of the hip control limb, fair action can be obtained with a 2- or 3-inch stump. The original type of artificial limb, which was held in place by shoulder straps, tends, with certain movements, to fall away from the stump when it is short. When a disarticulation at the *hip* is necessary, the modern pelvic socket type of prosthesis will be surprisingly satisfactory. All muscles except those of the buttock should be removed.

AMPUTATION NEAR THE KNEE. Amputations at this level are particularly adaptable to artificial limbs sustaining considerable weight, thereby lending stability to the prosthesis. The *Gritti–Stokes amputation* is performed at the knee joint; the lower end of the femur and posterior part of the patella are removed with the saw so that the patella can be rotated and approximated against the end of the femur. Since an end-weight-bearing stump is thus produced, the skin over the end of the bone should be the toughest available. Using a long anterior flap, the skin normally overlying the patella becomes the weight-bearing portion of the stump. The anterior half of the patella is anchored to the end of the femur, where it heals in place. This procedure has been modified by Callander (13), who makes long anterior and posterior flaps and saws across the lower end of the femur above the condyles just proximal to the abductor tubercle, removing the patella, so that the stump of the femur may fit into the tendinous patellar socket and thus allow weight-bearing. This amputation is becoming quite popular and can be fitted very satisfactorily with an artificial limb, utilizing considerable weight-bearing, the chief advantage of which is stabilization of the artificial limb.

AMPUTATION THROUGH THE LEG. As stated previously, optimum length of a leg stump is 5 to 7 inches. Weight is borne on the side of the head and under the tubercle of the tibia, against the conical shaped bucket of the prosthesis. For this reason, the patient can rarely stand all day on his feet because of skin irritation and pain at the site of the weight-bearing. The skin chafes and blisters, and hair follicle infections are common. However, the stump is easily fitted with a prosthesis, and the patient can learn to walk with very little limp. In women who do not need to be on their feet very long at a time, it is particularly adaptable because of the good cosmetic appearance. The fibula should be sectioned about an inch above the level of the tibia and the corners smoothed off well. Although many surgeons remove it entirely, its presence is helpful in rotating the prosthesis. Excision of the fibula is advisable, when possible, in short leg stumps because it yields a rounder and more conical stump. Amputations in the lower third of the leg are considered unsatisfactory by most surgeons because of poor circulation and increased sensitivity and by prosthesis makers because the long stump may actually interfere with the ankle mechanism. If not enough leg stump remains to preserve the optimum 6 inches of tibia, it

is still preferable to preserve a shorter length rather than do an amputation above the knee, because a stump of no more than 1 or 2 inches will aid greatly in controlling the prosthesis. In selected cases of peripheral vascular disease, a circular amputation 4 to 6 inches below the knee may avoid thigh amputation. The stump is closed with lateral flaps using deep sutures through skin, fascia, and muscle. Preliminary lumbar sympathectomy may be indicated in some cases.

AMPUTATION THROUGH THE FOOT. The only satisfactory amputations through the foot are the *transmetatarsal* and *metatarsophalangeal* procedures. The latter is much less applicable than the former. The *Lisfranc* and *Chopart* amputations are unsatisfactory because muscle balance of the stump is destroyed, with resultant deformity on many occasions. The principle of the *Pirogoff* amputation is satisfactory, but for success it is necessary that the resected portion of oscalcis and cut end of tibia unite; this union will not always take place satisfactorily. The *Syme* amputation is the most satisfactory amputation when a transmetatarsal amputation cannot be carried out. It results in an end-weight-bearing stump which will tolerate strenuous usage. To obtain a good Syme stump, this operation must be properly executed. The malleoli are not removed, but the tibia and fibula are sectioned not more than 1 cm. above the cartilaginous surface of the tibia, thus preserving the bulbous flare of the ankle and also the lower ligamentous anchorage of the fibula to the tibia. Amputation above the malleoli and above the inferior tibiofibular ligament is not a Syme amputation and results in an unsatisfactory stump. It is essential in the Syme amputation that the os calcis be removed subperiosteally so that the heel flap may firmly adhere to the lower end of the tibia. It is also necessary that the heel flap be accurately centered on the tibia. Failure to observe these details at operation and in postoperative care will result in a totally unsatisfactory stump, to which a prosthesis cannot be fitted. If the Syme amputation is not possible, it is then usually preferable to go several inches higher, leaving a stump of tibia equal to 6 or 7 inches.

AMPUTATION THROUGH THE SHOULDER. Many different types of skin flaps have been described for *amputation of the shoulder,* e.g., Kocher, Larrey, Dupuytren. A shoulder girdle amputation includes removal of the entire upper extremity with the scapula and most of the clavicle.

AMPUTATION THROUGH THE ARM AND FOREARM. The optimum levels and some of the other features of amputations in these regions have already been discussed. Anterior and posterior flaps of equal length are cut so that the scar will be on the end; the sides of the stump govern motion of the prostheses. Artificial limbs fitted to an arm stump are of little functional value, but are of great psychologic and cosmetic value. However, prostheses for the forearm are of considerable functional use (Fig. 6). The conventional type is equipped with a mechanical hand which is interchangeable with a utility hook; motions are controlled by straps from the opposite shoulder. With practice and training, accomplishments with these appliances for a forearm stump are astonishing (14, 15); the patient can readily learn to eat with both hands, write, tie his tie and shoelaces, and perform many other functions necessary in one's daily routine. However, Gillis (16) has very aptly emphasized that the type of upper extremity prosthesis must be chosen to meet the needs of the patient. For example, a hook which is very useful to a workman would have comparatively little value to a man whose vocation is politics.

Postoperative Care. Patients with amputations require more than the average postoperative care because of the *danger of infection and its seriousness when present.*

Postoperative care differs considerably, depending upon whether or not the wound was left open or closed. If an open amputation was performed, one of the most important features in postoperative care is application of traction on the skin of the stump and its maintenance until healing is well advanced. This is readily accomplished by gluing sterile circular stockinette to the skin of the remainder of the extremity, permitting several inches of stockinette to dangle below the end of the stump to which a rope for traction can be tied. Sufficient traction (5 to 10 pounds) is applied to bring the flaps down.

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ful phantom) is comparatively rare. For example, in a series of 2,284 amputees seen in American army hospitals during World War II, Ewalt and associates (19) noted that only 8 complained of a painful phantom. The phantom limb has been described as an hallucination (20). As time passes, the phantom usually disappears into the stump. The painful phantom is often difficult to treat; operation such as removal of an amputation neuroma seldom, if ever, helps. Other therapy should be tried. Rarely is resection of the sensory cortex (lobotomy) justified.

Rehabilitation. Obviously, all effort must be made to fit the stump with a prosthesis, although it is recognized that certain prerequisites must be met before this can be done. The important prerequisites may be enumerated as follows: 1. adequate shrinkage of the stump; 2. flexible skin over the stump without adherent scar; and 3. well-developed muscles to control the stump.

It is essential that the fitting of the limb should not be postponed, lest sufficient muscle and bone atrophy take place to seriously delay walking. Such delay in starting function with the artificial limb is particularly serious in the aged and may even be the primary factor in inability of the patient to learn how to use a prosthesis. Graded muscular exercise is important, particularly in lower limb amputees; for bilateral knee amputees, proper balance is impossible without strong abdominal muscles.

SHRINKAGE OF THE STUMP. This is one of the most important prerequisites necessary to fitting a prosthesis. Shrinkage takes place for six to nine months after operation. It can rarely be accomplished to such a degree of rapidity as to allow fitting of the prosthesis sooner than two months after operation. One of the most effective mechanisms of obtaining shrinkage is to apply elastic bandages to the stump (Fig. 7); this can be started as soon as the sutures are removed and healing has taken place. Another very effective method of obtaining shrinkage is utilization of weight bearing in a temporary prosthesis, which can be constructed as a mold of the stump made with plaster bandages. After the mold has hardened, a peg of adequate length is attached and fixed with more plaster (Fig. 8); it is held in position by proper straps over the shoulder and around the waist.

PREVENTION OF CONTRACTURES. Contractures usually develop in the preoperative period of the patient's illness and should be avoided if at all possible, since they may be very difficult to eliminate once they develop to a severe degree. In general, contractures must be corrected before the prosthesis can be fitted.

SELECTION OF PROSTHESIS. The surgeon must be very familiar with the mechanisms and types of prostheses, but the fitting itself is a specialty of its own and is better left to the personnel dispensing the limbs. However, the surgeon must tell the leg fitter what type of prosthesis is best suited for the individual patient; moreover, he must know whether or

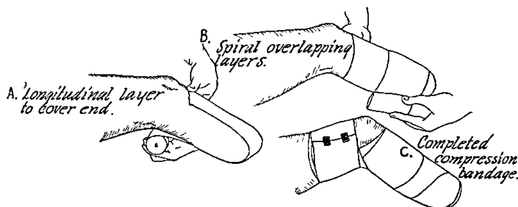


Fig 7. Technic of applying tensor bandage to stump to produce shrinkage. A, longitudinal layer to cover end. B, spiral overlapping layers. C, completed compression bandage. (Courtesy F. M. McKeever.)

As stated previously, the traction need not interfere with dressings. It will require at least six or eight weeks for healing to progress far enough to allow any secondary operation which will be necessary after most guillotine operations. If a small granulating area remains at the end of the stump, it can be excised and the skin flaps undermined sufficiently to allow closure without tension. If the bone end is long, the end may be freed and a small portion sawed off to allow closure. However, when bone is removed in the presence of an ulcer, there must be absolutely no evidence of infection remaining in the wound. After this reamputation operation as well as after the primary one, appropriate antibiotic therapy should be given for a few days to minimize possibility of infection. The treatment of the stump from the prosthetic standpoint is discussed later.

If the *stump has been closed*, the wound should not be dressed every day, but the temperature and pulse chart must be observed closely for an elevation which might be indicative of development of infection. Likewise, if the patient complains of pain in the stump, the dressings should be changed and the stump inspected. If there is sufficient redness, edema, and tenderness to indicate the presence of infection, a number of sutures must be removed to allow drainage. Frequently, it will be advisable to open the wound completely. In the presence of infection, the wound should be dressed and irrigated daily. Carrel Dakin treatment or application of zinc peroxide may be utilized. Wound secretions should be cultured as soon as infection is suspected so that specific immediate therapy may be instituted. When such a wound has been opened the skin flaps tend to retract. After the infection has subsided, it is, therefore, usually necessary to exert some type of traction on the skin to bring it down into its former position so that the stump will be covered adequately with soft tissue. It should be emphasized, however, that traction should not be applied to any stump when an acute infection is present. The stump should be placed in a comfortable position. Arms should be placed in moderate abduction. For the thigh and knee a slight amount of flexion is permissible, but elevation on pillows is to be condemned. To prevent muscle atrophy the stump must be fitted early for a prosthesis (9). Perhaps a still more important reason for making early plans for fitting a prosthesis is the effect on morale. In fact, the early fitting of a prosthesis is so important that a temporary appliance of fiber or equivalent material may be indicated (Thompson, 17). As soon as shrinking of the stump has been achieved, a permanent limb is fitted.

Complications. *Reamputation* is occasionally indicated when not originally planned. For example, osteomyelitis of the end of the bone, or tender bone spurs in the absence of infection may necessitate reamputation. Not infrequently, tender scars are so troublesome that a prosthesis cannot be worn comfortably. In such an instance, simple excision of the scar with interposition of some soft tissue, preferably subcutaneous fat and fascia (if the scar was adherent to the bone or directly overlying it) will be indicated but is not always successful. Local tenderness associated with a *neuroma* may justify excision of the end of the nerve, but not reamputation. White (18) has emphasized that repeated excisions of neuromas are contraindicated; if relief is not obtained by one excision, another excision at a later date will rarely be successful. Sympathectomy may be tried if local measures fail. Local pain, burning, and tenderness in the stump may be treated by sympathetic block or sympathectomy; on rare occasions, section of the rhinothalamic tract may be indicated. Occasionally an ulcer develops at the end of the stump and stubbornly refuses to heal, frequently because the bone is too long. Excision of a few centimeters of bone together with scar tissue or reamputation at a higher level will be indicated depending upon the circulation in the stump. If the bone has adequate coverage with soft tissue, simple excision of the ulcer and scar tissue may suffice. In any case, these secondary procedures *must not be performed until all evidence of infection*—such as induration, redness, edema—*has disappeared.*

Phantom limb refers to the complaint of many amputees of normal sensations in the absent extremity. A sensation of pain (pain-

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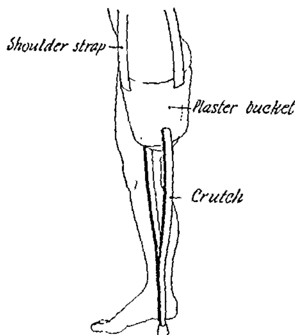


Fig. 8. Simple plaster pylon. Made from plaster bandages, crutch and webbing straps. (Courtesy F. M. McKeever.)

not it fits and meets the requirements of the stump.

Perhaps the best wood for prostheses is willow, and the best metal is duraluminum (alloy of aluminum) because it is light. A fiber made from rag pulp is often used because it is so readily adjustable. For upper extremity prostheses, laminated plastic is best suited for the socket. Leather is being used less and less, largely because it lacks stability and absorbs odors. The socket is the element requiring the greatest skill in construction. It is the portion of the prosthesis into which the stump fits and through which the stump motivates the prosthesis.

Cineplastic Amputations. This term may be defined as being any type of plastic operation on an amputation stump (usually on the upper extremity) which allows transmission of voluntary movement to the artificial limb. The procedure was first utilized by Vanghetti, an Italian, in 1898. At the present time the method is relatively unsatisfactory, but efforts toward development of such improvements should be encouraged. A tube flap of skin is made over the muscle to be utilized and threaded through an opening made in the body of the muscle whose function is to be utilized. The defect made by raising the tube skin flap is closed with or without a skin graft as indicated. After healing has taken place, a peg is placed through the opening and the ends of the peg attached to levers on the prosthesis so that, when the muscle contracts, the hand, for example, will open or close. Although delicate movements of fingers cannot be duplicated, the function of grasping and releasing objects with the mechanical hand should be possible if sufficient arm stump is available and the operation is successful. The points of attachment on the extremity are called "motors." To be effective, they should have at least a 2 or 3 cm. range in motion induced by contraction of the muscle. The pioneer work in cineplastic amputations has been done by Kessler (21). Details of progress made in the various aspects of amputation may be found in the publications by the National Research Council (22). These amputations have a very limited application but are, however, proving to be of some value in bilateral upper arm amputees, where cinematization of the biceps and/or the pectoral muscles supply valuable motors to motivate the prosthesis.

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may proceed to the point of perforation with comparatively few symptoms. For that reason, when acute abdominal manifestations suggestive of appendicitis develop in a diabetic patient, delay in operation is hazardous, particularly because such acute lesions as appendicitis and acute cholecystitis are less apt to subside and are more prone to progress to perforation than in nondiabetic patients.

On the other hand, it is not generally appreciated that patients in diabetic acidosis or impending coma may develop acute abdominal symptoms not unlike those of acute appendicitis, acute pancreatitis, and so forth, including nausea, vomiting, abdominal pain, rigidity, and leukocytosis. What a serious error it would be to submit such a diabetic patient with impending coma to operation! Usually, however, the differentiation can be made by the sequence of development of vomiting and pain. In diabetic acidosis, the vomiting is apt to precede the pain, whereas in appendicitis the pain precedes the vomiting. Routine examination of the urine for sugar reveals the existence of diabetes which, of course, should lead to the true explanation of the clinical picture.

Trauma in diabetics likewise must be treated with unusual care because any significant injury acts like an operative procedure by aggravating the diabetic state. In *fractures*, particularly, the insulin requirements will have to be raised considerably. For example, a diabetic remaining sugar-free on 20 to 30 units daily may require 70 to 100 units daily for many days or weeks following a severe fracture, such as one involving the hip or shaft of the femur.

Infections in diabetes call for an increase in the insulin requirements. Failure to appreciate this fact may result in acidosis or even coma. The explanation of this phenomenon is not clear, but the theory most commonly accepted is that, on such occasions, there is a decrease of endogenous insulin secreted by the pancreas. Greene and Keohen (2) found no evidence that the amount of fever played any role in the insulin needs.

Many other surgical diseases, including hyperthyroidism and cholecystitis, increase the intensity of diabetes. Naturally, the presence of the two diseases will complicate the therapy and require more skillful care.

The belief is sometimes expressed that elimination of such a disease as cholecystitis will decrease the amount of insulin needed. However, in an extensive study of 76 diabetic patients having had cholecystectomy at the New England Deaconess Hospital, Eisele (3) did not note any significant decrease in insulin requirements after operation. Control of cholecystic symptoms was satisfactory although complications as found at operation were much more common (22 per cent of the series had hydrops, empyema, gangrene, perforation, or pancreatitis), indicating that the need for surgical care of bladder disease is just as strongly indicated in diabetics as in nondiabetics.

The mortality rate for cholecystectomy will be no higher in diabetics than in nondiabetics, providing meticulous care is taken to control the diabetes and to treat complications skillfully.

Preoperative Preparation. The operative mortality in diabetics has dropped tremendously since the introduction of insulin, as shown in a survey of the literature by John (4) who noted that in 2,023 operations on diabetic patients before the advent of insulin the mortality was 24.2 per cent; whereas, in 14,251 operations performed with preoperative insulin therapy (but before the advent of chemotherapy), the mortality was only 5 per cent. Other factors are, of course, important in reaching a low mortality. For example, it is particularly important that the glycogen reserve of the liver be maintained. Satisfactory glycogen reserve can be attained only by the administration of a diet containing adequate amounts of carbohydrate, protein, vitamins, fluids, and so forth, along with proper insulin therapy.

Arteriosclerosis is frequent in diabetics. These patients should therefore be submitted to thorough examination, paying particular attention to the heart and kidneys, organs which are apt to be seriously affected by arteriosclerosis of the advanced type. Generally speaking, because of the features just mentioned, the best results in diabetic surgery will be attainable only by the utmost of co-operation between the internist and the surgeon. Lack of such joint effort perhaps accounts in part for the large variation in the mortality following operation (4 to 30 per

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SURGERY IN DIABETES

Surgical Diseases Unrelated to Diabetes
Surgical Diseases Secondary to Diabetes

Diabetes is a chronic metabolic disease, *largely hereditary, resulting from an insufficient* production or a diminished effectiveness of insulin, which is an internal secretion produced by *the islands of Langerhans in the* pancreas. The discovery of insulin has lengthened life considerably for diabetics, thus increasing their need for surgical therapy. Even if the insulinase inhibitors, recently introduced in the treatment of certain types of diabetes, supplant insulin, they will probably not affect the surgical aspects of the disease.

There are a number of surgical lesions (particularly infections) which increase the severity of diabetes. This fact must be appreciated, and the dosage of insulin increased lest diabetic coma develop as a result of the infection. Conversely, *it is true that diabetic* patients are prone to develop infection or gangrene of the toes and feet; McLaughlin and Wiedman (1) noted that one or the other of these lesions was present in 6.7 per cent of 802 *diabetics admitted to their hospital.*

Diabetics, particularly adults, appear much older in many ways than their true age. This is explained, in part, by the fact that they are much more prone to develop arteriosclerosis. Joslin has stated that a diabetic patient is as old as his real age plus the number of years he has had diabetes. The arteriosclerosis which develops is generalized in character, affecting the coronary and renal vessels, as well as those of the extremities.

Wounds in diabetic patients, in the absence of complicating factors, heal as readily as wounds in nondiabetics *but because diabetics* have a lowered resistance to bacteria, infection is more likely. It has been shown that the blood serum of diabetics has a lower opsonic index toward tubercle bacilli, staphylococci, and streptococci than the serum of normal people.

This discussion of surgical conditions in diabetes will be divided into a consideration of lesions unrelated to diabetes and lesions secondary to diabetes. The latter group is much more serious than the former, requires a different type of therapy, and is associated with a much higher mortality.

SURGICAL DISEASES UNRELATED TO DIABETES

Numerous surgical lesions requiring operation develop in the presence of diabetes but are entirely unrelated thereto. Operations under such circumstances may be carried out with comparative safety, so long as the diabetes *is under control. This requires* special care because any anesthesia and operation temporarily aggravate the diabetic state. With this precaution met, most surgeons have such fortunate results in this group of patients *that they do not consider* diabetes as a contraindication for either emergency or elective operation.

However, it must still be remembered and emphasized that even a controlled diabetic patient is distinctly not as safe a risk as a nondiabetic patient, e.g., the incidence of pneumonia in abdominal operations in the presence of diabetes is greater *than in* nondiabetic patients. The mortality following operations for carcinoma is considerably higher when there is a coincident diabetes.

Clinical manifestations in many acute sur*gical conditions, particularly* those within the abdomen, are milder when they develop in diabetes, e.g., an acutely inflamed appendix

may proceed to the point of perforation with comparatively few symptoms. For that reason, when acute abdominal manifestations suggestive of appendicitis develop in a diabetic patient, delay in operation is hazardous, particularly because such acute lesions as appendicitis and acute cholecystitis are less apt to subside and are more prone to progress to perforation than in nondiabetic patients.

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cent) in diabetic patients in the various clinics throughout the country.

Elective operations should be preceded by a preliminary period of preparation and study so that the insulin requirements may be fully understood. Though protamine insulin has been of considerable value in the treatment of the surgical diabetic patient, its prolonged action may serve as a disadvantage, making it necessary sometimes to resort to feedings at bedtime and between meals. In general, it is more difficult to use protamine insulin in children. The amount of carbohydrate, protein, and fat in the diet will naturally depend on the severity of the diabetes and will vary from 175 to 250 gm., 75 to 80 gm., and 70 to 90 gm., respectively. If malnutrition is present, administration of a high protein diet (1.5 to 2.0 gm. per kilogram) should be given preoperatively until operability is satisfactory.

Nutritional preoperative preparation varies somewhat, depending on the severity of the diabetes. Breakfast and its insulin is omitted; the usual dose of insulin (preferably depot insulin) and 60 gm. of glucose by mouth may be given two or three hours before operation. Intravenous glucose (1,000 ml. of 5 per cent) may be substituted for the oral glucose. Protamine insulin is very satisfactory as the preoperative dose because of the excellent protection during the operation, but should not be given if it has not been used in the routine care of the patient previously. Hypodermoclysis or intravenous fluids are not given before operation unless there are specific indications. The dose of drugs, preoperative and otherwise, should be decreased to slightly under the average dose because diabetic patients are somewhat less tolerant to drugs than are nondiabetic patients.

In *emergency* operations there will obviously not be sufficient time to make the urine sugar-free. The administration of such massive doses as to attain this effect in a few hours would be unsafe because of the danger of severe hypoglycemia. However, if possible, the urine should be free from diacetic acid.

Anesthesia in Diabetes. No single anesthetic agent can be used effectively and safely as a routine in diabetic patients. Certain of the gases, including nitrous oxide, ethylene, and cyclopropane are relatively innocuous. One of the greatest anesthetic dangers in diabetic patients lies in the production of acidosis. Unlike the three agents mentioned above, prolonged administration of ether has a distinct tendency to produce acidosis. Furthermore, ether results in hyperglycemia, either through defective utilization of carbohydrates, by prevention of conversion of dextrose to glycogen, or by depletion of hepatic glycogen. Asphyxiation of tissues may be partly responsible for these changes. At any rate, anoxia should be meticulously avoided, regardless of the agent used. Chloroform should never be used on account of the severe damage inflicted by it upon the liver. Avertin should not be used because of its deleterious effect on the liver which, however, is obviously not as pronounced as that produced by chloroform.

Local anesthesia is, in general, the safest and should be used whenever feasible. For amputations, spinal anesthesia (50 to 75 mg. procaine) will probably be as free from deleterious effects as any other type. However, in doses large enough to permit abdominal operations, spinal anesthesia is probably no less hazardous than a general anesthetic. For abdominal operations gas-ether anesthesia (utilizing nitrous oxide or perhaps ethylene) will be as safe as any other. Intravenous anesthesia (e.g., sodium pentothal) may be used when relaxation need not be complete or prolonged, but must be given with considerable caution.

Postoperative Care. The maintenance of proper fluid intake is an especially important obligation in the care of diabetic patients following operation. If the operation is a major celiotomy and oral intake is limited or absent during the first 24 to 48 hours, the intravenous route will be indicated. Since there is normally a mild retention of sodium chloride and water for 24 to 48 hours after operation, it is important to avoid excessive infusion of fluids (not more than 30 ml. per kilogram and a total of 4 gm. of sodium chloride) during the first 24 hours unless an electrolyte deficiency existed at the time of operation. In this case, it should be corrected before the anesthetic is started. Intravenous glucose will have to be covered by insulin, administered in amounts equivalent to that needed preoperatively for a given amount of carbohydrate. In

general, intake and output should be equal and adequate.

To prevent the possible development of insulin shock, relatively small doses of insulin at frequent intervals are preferable. The interval between doses for a day or two following operation should be shorter than preoperatively because the duration of its effect is shortened. It is preferable to administer too little insulin rather than too much. Blood sugar determinations are supposedly more accurate than urine analyses in determining the amount of insulin to administer, but each test should be made at intervals of four to eight hours during the first day or two. It should be remembered that slight glycosuria does little harm whereas insulin coma (hypoglycemia) may give rise to serious or even fatal consequences, even though recognized early and treated. For this reason, little or no attempt is made to make the urine sugar-free during the first three or four days postoperatively. However, the urine must be watched for acetone, and insulin with ample fluids must be given as indicated.

All nurses and physicians attending the diabetic patient should be trained to detect the manifestations of insulin shock. Such symptoms as weakness, sweating, pallor, hunger, and mental confusion demand consideration of such a diagnosis. The problem can be settled by a blood sugar determination. However, the condition is so serious that it should be recognized and proper therapy (intravenous glucose) instituted without waiting for the blood sugar report.

The usual postoperative instructions, such as breathing exercises, frequent changes of position, and ambulation, are ordered. If the operation has been of a type resulting in bacterial contamination (e.g., colectomy), prophylactic chemotherapy—such as 600,000 units of penicillin and 2 grams of streptomycin per day—is given, particularly since diabetic patients tolerate infection poorly. If appetite is regained slowly, the dietitian should be consulted, and acceptable foods desired by the patient made available. More details of preoperative and postoperative care in diabetics may be found in a publication by Shuman (5).

McKittrick and Root (6) suggest a very simple and practical method of determining the amount of insulin required during the first few postoperative days, namely: "(1) Test the urine (Benedict's test) every four hours and (2) give insulin (crystalline), 15 units if the reaction is red, 10 units if it is yellow, and 5 units if it is yellowgreen." Such procedure is obviously only an approximate method of determining the amount of insulin needed but, since a definite mathematical method is unavailable, this simple rule will be found useful.

Oral feedings, including fruit juice and ginger ale, are administered as soon as tolerated, followed, on the second or third day, by portions of solid food more readily tolerated. Attempt should be made, particularly after the first 24 hours, to reach a daily carbohydrate intake of 100 to 150 gm. If the oral intake falls short of this amount, the remainder may be given as 5 per cent glucose intravenously or as 2.5 per cent glucose in physiologic sodium chloride solution subcutaneously.

SURGICAL DISEASES SECONDARY TO DIABETES

Incidence. Among the complications of diabetes or surgical diseases secondary to it, atherosclerosis is perhaps the most significant; it occurs particularly in the coronary arteries, renal arteries, and aorta. Atherosclerosis refers particularly to the degenerative aspects of arteriosclerosis. These arterial changes are much more common in diabetics than in nondiabetics. For example, in 1,214 diabetic autopsies Bell (7) noted that coronary atherosclerosis caused three times as many deaths (in females) in diabetics as in nondiabetics; this lesion was twice as common in males as it was in females. In his series, gangrene was 40 times as frequent in diabetic as in nondiabetic females past 50 years of age. Bell also noted that in those persons past 40 years of age atherosclerosis was the cause of death in 54 per cent of diabetics compared to 29 per cent in nondiabetics. Other important, complicating diseases more commonly observed in diabetics than nondiabetics are cataracts, retinopathies, prostatic hypertrophy, and other neuropathies discussed in detail by Goodman (8). The increased incidence of infection is perhaps of more importance than that of any of the conditions men-



Fig. 1. Deep plantar abscess in foot of a diabetic. Large patches of gangrene are also present. In this case amputation was necessary. Without the development of gangrene this abscess would have been treated by incision as in a nondiabetic.

tioned above; the various aspects are discussed in detail below.

Infections. As stated previously, infection is a common complication of diabetes. Although it may develop anywhere in the body, it is much more common in the lower extremities. Discussion of infection in this chapter will, therefore, be limited to those in the foot and leg. Years ago, before the advent of chemotherapy, infection associated with gangrene in the extremities of diabetics was very serious and often made emergency amputation necessary (9). Now infection, even in the presence of gangrene, is treated conservatively with simple surgery and antibiotics. After subsidence of the infection, gangrene is treated as discussed later in this chapter.

A serious infection may frequently develop in the foot and leg of a diabetic patient with (Fig. 1) or without gangrene. So many features are different from those in gangrene that the two conditions should be discussed separately. In the first place, infection is not dependent upon arterial deficiency and may start spontaneously or follow slight trauma. Such local manifestations as redness and swelling are present; but pain and tenderness are apt to be minimal. Spread may occur rapidly from the toe into the adjacent soft tissues, plantar spaces, and often involves underlying bone, partly because of the relative absence of pain. There is, indeed, a real hypoesthesia due, no doubt, to diabetic neuropathy. Sensation may be completely absent, and incisions can often be made painlessly without anesthesia. The amount of fever is extremely variable as is also leukocytosis. The increase in severity of diabetes by infection has already been discussed; this feature and the tendency toward rapid spread of the infection constitute reasons why the infection should receive prompt attention and treatment. Yet the prognosis in the face of neurologic changes without arterial impairment is unusually good.

Treatment. The need for prophylactic measures in the treatment of infections of the feet cannot be emphasized too strongly. Since gangrene or infection is so apt to follow trivial injuries in diabetes, it is essential that diabetic patients avoid trauma to their feet. Epidermophytosis should be watched for at all times and treated in its incipiency. Hot-water bottles, cold weather, new shoes, wrinkles in hosiery, electric pads, and the like, may cause trivial injuries which may serve as the instigator of serious trouble. The care of nails, corns, and so forth, should be entrusted to someone (not necessarily the patient) who is careful and experienced. Amputation need be considered only rarely, but incision with adequate drainage is urgently indicated when pus is present. The differentiation between a cellulitis and an abscess is frequently very difficult because of the absence of the usual inflammatory signs. Moreover, the infection burrows so rapidly and readily along fascial planes and tendons that any pus present will

not be under enough tension to produce fluctuation.

In general, an infection in a diabetic is treated the same as in a nondiabetic and often heals remarkably well. It is, nevertheless, more important that incision not be delayed when pus is present. Moreover, the incision for drainage must be adequate and must extend upward as far as the infection has burrowed. Rubber drains are used as indicated; but, in general, incisions should be sufficiently generous not to require drains to maintain drainage. Osteomyelitis of the tarsal bones also occurs and, like soft tissue infection, heals well with adequate drainage and chemotherapy, particularly in the presence of neuropathy.

When infections develop in the hand they are likewise serious because of the rapidity with which they spread along the sheaths, fascial spaces, and even subcutaneous tissue.

Chemotherapy should be instituted immediately, given in large doses, and maintained for several days after the signs of infection disappear. Penicillin in doses of 500,000 to 800,000 units and streptomycin in doses of 2 or 3 gm. per day may be tried initially. In view of the added danger of gangrene in diabetes, a culture should be taken as soon as possible, and sensitivity of the organism to the various antibiotics determined. After this data is obtained, the antibiotic shown to be most effective in vitro should be used, unless the infection has already subsided under the initial therapy.

Carbuncle. It is important to emphasize that carbuncles are much more serious in diabetic patients than in nondiabetics and, therefore, require more care in therapy. They are usually located on the back of the neck and commonly occur when the diabetes is out of control. They are so definitely related to diabetes that all patients with carbuncles should at once have a urine examination. Carbuncles, like other infections, increase the severity of diabetes, making it necessary to watch the urine and blood sugar daily. It will be necessary to increase the amount of insulin while the infection increases in intensity and decrease it as drainage is established. To prevent development of carbuncles, diabetic patients should not shave their necks and should, under no circumstance, squeeze or irritate hair follicle infections.

Carbuncles in diabetic patients may be treated with or without surgical drainage; the decision is now greatly influenced by the effect of chemotherapy. It is frequently difficult to determine when drainage should be established. Ordinarily, if the carbuncle is producing no fever or pain, and still remains relatively small in size, treatment may consist of radiotherapy and intensive chemotherapy. Local tenderness, fever, and especially fluctuation are usually indications for incision to establish drainage. The patient should be confined to bed and instructed to eliminate activity which would result in movement of the neck. Since the offending organism is a staphylococcus, penicillin is ordinarily effective but frequently is not, due to the increasing resistance of this organism.

Gangrene. Diabetic gangrene is serious because of its frequency and poor prognosis unless treatment is carried out very accurately. In a large series of cases collected from the literature, John (4) noticed an incidence of 5 per cent, and McLaughlin and Wiedman (1) of 6.7 per cent, in diabetic patients. The development of gangrene is determined by the degree of vascular occlusion (arteriosclerosis) and bears little relationship to the severity of the diabetes. The gangrene may be "dry," i.e., of the type usually seen in arteriosclerosis, but is more apt to be "wet" because of the high incidence of infection.

Diabetic gangrene may occur anywhere on the body but is usually located on the toes or feet, where it starts as a small gangrenous area (Fig. 2). Occasionally, the process is superimposed upon an infectious process because of the interference to circulation by the edema, and so forth, incident to the infection (Fig. 3). Rosenberg and London (10) have very appropriately emphasized that "in a limb presenting a gangrenous lesion, the prognosis may be paradoxically better for the diabetic than for the nondiabetic."

Pain at the site of the gangrene or of the intermittent claudication type in the leg is apt to be minor in character. Examination of the extremity proximal to the gangrene will reveal a variable degree of impairment of blood supply; the skin is apt to be dry, thin, and parchmentlike, and the nails dry and



Fig. 2. Gangrene of the fourth toe in a diabetic. In this case, without involvement of the foot, transmetatarsal amputation just proximal to the metatarsal heads is indicated.

brittle. Other manifestations of damage to the blood supply may include pallor of the foot upon elevation and a slowly developing rubor or cyanosis upon dependency. The dorsalis pedis, posterior tibial, and frequently the popliteal pulses on the affected side are apt to be absent. If infection is present, there will be edema, redness, and so forth, as described later in this chapter.

TREATMENT. Preventive measures are of the greatest importance in diabetic gangrene, as has been discussed under Infections. In definitive therapy, rest in bed is, of course, imperative; the leg should be put in a position where blanching of the foot is minimal and precautions taken lest decubital ulcers develop. If the gangrenous area is dry and not infected, dry sterile dressings should be applied to prevent contamination and subsequent infection. If infection is present, wet dressings consisting of physiologic saline, 50 per cent alcohol, or some weak antiseptic should be applied. In either case, the foot should be protected with a cradle. Should the infection become fulminating, increased chemotherapeutic coverage may be necessary, and refrigeration in preparation for amputation may be indicated.

The major definitive pattern of treatment of diabetic gangrene has changed considerably during the past several years and the mortality reduced greatly. Amputation has become much less radical. The predominant type has changed from leg or thigh to local (i.e., toe or part of the foot). For example, Regan and associates (11) noted that in their experience between 1933 and 1939 the percentage of thigh amputations was 71 per cent and toe amputations 29 per cent. In the period between 1945 and 1948 the frequency of these types of amputation was reversed—thigh and leg being 30 per cent and toe amputations 70 per cent. In their last series of patients, a large proportion of the major amputations were in patients who had an unsuccessful local (toe) amputation. Moreover, it has become more and more apparent that the clinical impression as to the state of the circulation is by no means a correct indication as to how successful a local amputation might be. Years ago, before the advent of chemotherapy, local amputation instead of a high amputation was a serious error and often resulted in the death of the patient. In recent years, largely because of chemotherapy, local amputation seldom results in death of the patient even though the stump develops gangrene or fails to heal. Regan and associates have reported a mortality rate of 4.1 per cent following amputations in diabetics in a period between 1945 and 1948 and a rate of 8.8 for the period between 1940 and 1945, indicating that improvement in mortality figures continues. They likewise reported that in the three periods, 1933 to 1939, 1940 to 1944, and 1945 to 1948, successful local amputations (toe or part of the foot) had changed to 46 per cent, 63 per cent, and 86 per cent respectively. In local amputations of the toe only, closure of the stump will usually be impossible or unjustified. After granulations form, skin grafts are applied.

McKittrick and associates (12) favor transmetatarsal amputation over amputation of one or two toes, partly because removal of a toe, especially the great toe, alters the "weight bearing and increases the vulnerability of the remaining toes." The operation is indicated primarily in the presence of gan-



Fig. 3. Extensive diabetic gangrene of the foot. The patient was a 45-year-old female. A moderate amount of infection was present, as is commonly noted in diabetic gangrene, thereby making amputation more urgent than in gangrene due to arteriosclerosis alone. Note the cyanosis below and distal to the necrotic area with impending gangrene of the toes.

grene of one or more toes without gangrene of the dorsal or plantar aspect of the foot. Obviously, there must not be any acute infection.

Wheelock, McKittrick, and Root (13) have indicated that there are two groups of diabetic patients for whom transmetatarsal amputation may be indicated. The smaller group consists of patients who have very good blood supply but who have neuropathy or severe infection. The operation may be performed to eliminate a chronic or recurring ulcer on the palmar surface of the forefoot (Fig. 4A) or to reconstruct a foot after an acute infection has destroyed part of it, and all infection has been eliminated. The second, larger group consists of patients with arterial insufficiency. Usually the pedal pulses are absent. Areas of skin necrosis may be present on one or more toes. Ulcers on the base of the great toe (Fig. 4B) are best treated by transmetatarsal amputation. There must be no necrosis on the dorsum, proximal to the metatarsal phalangeal joint. In general, the operation cannot be done unless the local condition is stabilized. This is achieved by bed rest, antibiotics, and surgical drainage if necessary. The above authors emphasize that three weeks may be required to obtain this stabilization; rarely, more time is required to obtain it and to arrive at a decision concerning the type of operative procedure to perform. Details of operative technic and postoperative care are described by these authors. Of 433 transmetatarsal amputations performed by them, 67 were classified as in the neuropathic-infection group and 366 in the arterial-insufficiency group. The mortality rate in the entire group was 1.1 per cent; initially successful results were recorded in 83 per cent, and immediate failures in 15.7 per cent.

Smithwich (14) reports that if the temperature of the skin at the site of amputation is 75° F. or more after exposure of the extremity to a room temperature of 68° for one hour or if, after blanching of the foot by elevation,

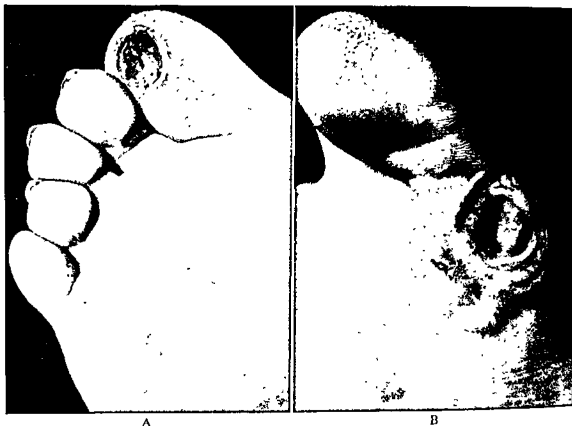


Fig. 4. Types of ulcers encountered in diabetes. In A there is an ulcer on the palmar surface of the great toe but there is also a patch of gangrenous skin on the dorsal surface; this foot is best treated by a transmetatarsal amputation. In B there is a penetrating ulcer at the base of the great toe without any gangrene. Transmetatarsal amputation is also indicated here but the edge of the ulcer encroaches closely on the expected suture line between the skin of the dorsal and ventral surfaces.

flushing in the dependent position begins in 20 seconds or less, collateral circulation is adequate for local amputations.

Sympathectomy is very helpful in diabetic gangrene, and in patients with minimal gangrene or ulceration it will promote healing in many patients without necessity of amputation.

Local amputation is much preferable to a high amputation (e.g., supracondylar) because the mortality rate is much lower and function is greatly superior. In fact, scarcely more than 50 per cent of diabetic patients having a supracondylar amputation will get back to work or wear prostheses successfully.

Miscellaneous Complications. *Furuncles.* Furuncles are also prevalent in diabetic patients and commonly become multiple (furunculosis). All patients with furunculosis should have their urine examined for sugar. Treatment is usually conservative, incising the larger ones as indicated (see also p. 91). Chemotherapy should be instituted, particularly if several furuncles are present. *Cholecystitis* cannot be classified as a true complication of diabetes, but it is true that the incidence of gallbladder disease is higher in diabetic than in nondiabetic patients. Some observers go so far as to state that in certain instances cholecystectomy will prevent the development of diabetes; obviously, proof of this is not at hand and would be difficult to obtain.

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20

NEOPLASMS AND CYSTS: CLASSIFICATION AND SURGICAL PATHOLOGY

Malignant Neoplasms
Benign Neoplasms
Cysts

The term neoplasm is commonly referred to as "tumor" which, however, is not a synonym. The term *tumor* really refers to a swelling which, in general, may be classified into two general groups, inflammatory and neoplastic. This terminology, moreover, is not exact, because a neoplasm, such as keloid, may actually follow an injury. Certain cancers, too, follow chronic irritation; and there is some theoretical and experimental evidence that neoplasms are in reality expressions of repair, exaggerated or gone wrong. Nevertheless, the division into inflammatory and neoplastic tumors serves a useful purpose in diagnosis when one is confronted with a swelling of unknown etiology. Inflammatory tumors are discussed under their respective causes. A few congenital tumors that are not neoplastic—such as meningocele and spina bifida—are considered under cysts.

Neoplasms may be divided into two great groups, malignant and benign, but some have characteristics which are not consistent with either group. Both groups, moreover, have one feature in common, i.e., they are formed by the abnormal and purposeless multiplication of previously normal cells. When benign, the new growth resembles closely the tissue from which it originated; the cells are arranged in orderly fashion and, though the tumor may attain great size, it never jeopardizes the life of the host except that it may involve vital functions by pressure and occasionally by functional activity. Malignant neoplasms, on the other hand, consist of abnormal cells which tend, more or less, to approach the undifferentiated embryonic type; they are not orderly in growth, but invade and destroy adjacent tissues or spread to distant parts of the body and lead finally to the death of the individual. The reader is referred to the texts by Ackerman (1), Boyd (2), and others for detailed morphologic descriptions of the various types of neoplasms. The following classification, though in some cases imperfect or arbitrary, will be used in this text. In the next chapter, the general principles of *therapy* will be discussed.

Classification

A. Malignant Neoplasm. Etiology, clinical characteristics, microscopic features, types (carcinoma and sarcoma), and treatment
   I. Carcinoma (epithelial)
      1. Carcinoma of the skin and squamous mucous membranes: (*a*) Squamous cell carcinoma, (*b*) basal cell carcinoma, (*c*) malignant melanoma, (*d*) Paget's disease of the nipple
      2. *Carcinoma of glandular origin* (breast, urinary and genital tract, and other internal organs)
      3. *Miscellaneous carcinomas*
   II. Sarcoma (mesodermal)
      1. *Fibrosarcoma* (fibroblastic or spindle cell sarcoma)
      2. *Bone sarcoma* (classification, general features and types, i.e., osteogenic and nonosseous (or miscellaneous) sarcoma
      3. *Sarcoma of lymphoid tissue:* (*a*) simple lymphoma, (*b*) leukemia, (*c*) Hodgkin's disease, (*d*) lymphosarcoma
      4. *Miscellaneous sarcomas:* (*a*) liposarcoma, (*b*) rhabdomyosarcoma, (*c*) thymoma

III. Brain tumors
Neurocytoma

B. Benign Neoplasms. Etiology, clinical characteristics and types (based on cell of origin)
- I. Connective tissue origin
  1. *Fibrous tissue tumors:* (*a*) keloid, (*b*) simple fibroma, (*c*) epulis, (*d*) giant cell tumor
  2. *Fatty tissue tumors:* (*a*) lipoma, (*b*) xanthoma
  3. *Bone and cartilage tumors:* (*a*) osteochondroma, (*b*) chondroma, (*c*) bone cyst, (*d*) benign giant cell tumor, (*e*) multiple cystic disease
- II. Nervous tissue origin
- III. Blood vessel origin
  1. *Capillary hemangioma*
  2. *Hypertrophic hemangioma*
  3. *Cavernous hemangioma*
- IV. Lymphatic origin
  1. *Lymphangioma*
  2. *Thymoma*
- V. Muscle tissue origin (myoma, leiomyoma)
- VI. Mixed tissue origin
  1. *Mixed tumor*
  2. *Teratoma*
- VII. Epithelial cell origin
  1. *Adenoma*
  2. *Epithelial benign tumors of the skin:* (*a*) wart, (*b*) cutaneous horn, (*c*) mole (benign melanoma)
  3. *Jaw tumors:* (*a*) adamantinoma, (*b*) dentigerous cyst, (*c*) odontoma, (*d*) osseus tumors (fibrous osteoma)

C. Cysts
- I. Retention cysts (galactocele, mucocele, ranula, wen)
- II. Degeneration cysts
- III. Neoplastic cysts (ovarian, bone)
- IV. Dermoid cysts
- V. Congenital cysts (branchial cleft, thyroglossal duct, meningocele, spina bifida, polycystic disease)

A. MALIGNANT NEOPLASMS

Etiology. There are many theories as to the etiology of malignant neoplasms, but it is generally admitted that the cause is still unknown. One of these theories is the *embryonal theory*, usually associated with the name of Cohnheim, who assumed that the tumor originated from an embryonic rest and that its malignant quality is simply the fetal power of growth carried into adult life. This undoubtedly applies to some congenital kidney tumors in childhood and perhaps to teratomas which become malignant. Another theory is that of *cell autonomy* which offers a conception of tissue tension that restrains growth. According to this theory, chronic irritation is one of the factors which enables certain cells to overcome this balance or restraint and allow rapid growth. Still another belief is that a malignant tumor is in reality an *infection*. For example, at least one type of experimental tumor, the Rous chicken sarcoma, is transmissible by a filterable agent, and is presumably of virus origin. At least two human tumors are of virus origin. In plants, a type of malignant growth has been associated with a complex protein molecule, the tobacco virus disease. The theory of an *inherited tendency* is now subject to intensive experimental and clinical study. In mice, its importance was thought to have been amply demonstrated, until the discovery of an agent in milk (Bittner, 3), the ingestion of which profoundly influenced the subsequent incidence of cancer of the breast in succeeding generations. This new factor has greatly increased the complexity of the factor of heredity. Nevertheless, a few types of neoplasms, such as polyposis of the colon and multiple osteocartilagenous exostoses, seem to have a definite hereditary tendency. Details of carcinogens and other etiologic factors will be found in the following chapter.

The greatest recent advance in research as to the cause of cancer is the discovery that certain chemicals (e.g., hydrocarbons and sterols) will produce cancer when injected into rats and mice (4). Such chemicals are called carcinogens. They are not normally present in the body but are closely related to many compounds which are present (5). This important line of investigation furnishes a definite basis for a *chemical-metabolic theory* for the cause of cancer. The favorable influence of chemotherapy (6) on certain types of cancers lends support to this theory. The well-known effect of sex and adrenocortical hormones (7, 8, 9) on prostatic and breast cancer also points to some metabolic abnormality in cancer. The theory that *acute trauma* may cause cancer is of more practical than scientific importance. The evidence is conflicting, but the question arises more often in sarcoma, particularly bone sarcoma, than carcinoma.

A history of trauma is so frequently given in various diseases that its relationship is always open to suspicion. Nevertheless, the matter has medicolegal importance, for courts have, on occasion, recognized such a relationship and have awarded large compensation claims even though scientific evidence in its favor is almost completely lacking.

Malignant disease is serious because it is a frequent cause of death (ranking second to heart disease), and cure is impossible without early diagnosis and adequate treatment. Another serious feature is that the recorded incidence of malignant disease is apparently on the increase (10), having doubled during the past 40 years. This increased frequency may not be a cause for alarm since part of this is undoubtedly due to improvement in diagnostic accuracy (11). Moreover, greater numbers of persons now attain the age when cancer is prevalent. In the United States, 60 per cent of cancer deaths are in patients over 45 years of age. In New York City, the proportion of persons over 45 is one third greater than a generation ago.

Clinical Characteristics. The earlier the lesion, the more difficult it is to make a diagnosis of cancer. It should be emphasized, however, that with thorough general and perhaps special examinations, the detection of cancer in its early stages is possible. The clinical manifestations of malignant disease depend of course on its site. Certain general characteristics, however, may be described, although most of them are obvious *only in the visible (i.e., external) types of cancer.*

(*a*) *Continued or progressive growth*, as well as progression of symptoms, is an important feature. Malignant tumors in most instances grow without interruption, whereas benign tumors stop growing after attaining a certain size.

(*b*) Local recurrence (or really local persistence) follows incomplete removal of a malignant tumor *but sometimes also of some benign tumors.*

(*c*) Metastasis is the most characteristic feature of cancer and is usually the most important factor in the fatal outcome. Metastasis is the spread of the growth, usually by way of the lymphatics or blood vessels, to regional lymph nodes and distant organs (*as the liver, lung, brain*). *Enlargement of lymph nodes* adjacent to an ulcerating carcinoma, however, may be due entirely to secondary infection and not to metastasis. Although metastasis is usually assumed to occur only by way of the lymphatics and the systemic and portal veins, an additional mode of spread has been postulated by Batson (1940), who has presented evidence that the system of vertebral veins (overlying the lumbar and thoracic vertebrae) plays an important role in metastasis. *Such channels would explain, for example, how metastasis to a vertebra might develop secondary to an abdominal cancer without involvement of the lung and without transmission through the lung.* According to Batson, the cancer cells are forced into the involved areas through the vertebral veins and collaterals by sudden changes in pressure. The various mechanisms of spread of carcinoma by implantation, venous emboli, and the like, are described in detail in Chapter 21.

(*d*) Local invasion by contiguity is another manifestation of most malignant tumors and may lead to much tissue destruction. *This invasive property resembles that exhibited by certain types of infection.*

(*e*) Hardness or firmness is an important diagnostic feature of most types of cancer, but is obviously of bedside value only when the tumor can be felt, as in the breast, rectum, mouth, or skin. This hardness is usually produced by excessive fibrous tissue which, however, varies greatly in different tumors. A sarcoma, for example, is apt to be *so cellular and vascular that it will have a soft consistency; scirrhous cancer, on the other hand, contains so much* fibrous tissue that it is often stony hard.

(*f*) Carcinoma, in general, is a disease of later adult life though not infrequent in those below 40 years of age. Sarcoma, on the other hand, respects no age group.

(*g*) Ulceration is frequent *in cancer of epithelial surfaces and, moreover, tends to progress (Fig. 1). In the* skin and mucous membranes, the edges of the ulcer are elevated, hard, and firmly elastic. Cancer of the mucous surfaces is especially prone to ulcerate, e.g., carcinoma of the stomach, *colon*, cervix, bronchus, lip, and tongue.

(*h*) *Bleeding is only occasionally encountered in the superficial malignant lesions of* the skin, but is frequent in carcinoma of the



Fig. 1. Extensive ulceration and bleeding in a far advanced fungating carcinoma of the neck.

colon, stomach, cervix, and bladder. The hemorrhage, though slight, is apt to persist and on many occasions leads to an insidious increasing secondary anemia.

(*i*) Disability as a characteristic of cancer is not of diagnostic importance since it occurs late and may be caused by any tumor or any type of inflammation. Cachexia and asthenia are present only in the terminal stage of cancer and are due, at least in part, to such effects of ulceration as bleeding and secondary infection. This is of practical importance because, in some instances, removal of an ulcerating cancer for its symptomatic relief may be justified even though the tumor has already metastasized and there is no hope of complete removal and cure. Cachexia and weakness, when present without ulceration, were formerly taken to indicate that the cancer may act as a true parasite, growing within and ultimately destroying its host. While this is probably true when the tumor involves vital functions or has metastasized widely, it is now recognized that starvation is frequently the basis for cancer cachexia, especially with ulcerating lesions. Starvation in cancer, in the presence of normal gastrointestinal function, is due to anorexia and can often be controlled, if indicated, by special methods to increase the nutritional intake (see Ch. 9). Pain as a symptom of cancer is present only in the terminal stages of the disease, except when the tumor irritates nerve endings by pressure or invasion or is growing rapidly in dense structures such as bone. The absence of pain in the early stages of many cancers is, of course, unfortunate because it increases the difficulty of early diagnosis.

(*j*) A fatal outcome of cancer is inevitable unless the entire tumor is completely removed or destroyed. Although, as emphasized by Everson and Cole (12), spontaneous cures have undoubtedly occurred, they are too rare to be of significance in diagnosis and treatment. Variations in duration are not uncommon, especially in the aged.

(*k*) Sensitivity to x-ray and radium is a characteristic of malignant disease which is very important in therapy; however, certain benign neoplasms share this sensitivity.

Microscopic Features. Because clinical diagnosis is often difficult it frequently becomes necessary to resort to microscopic examination of the suspected lesion. Such a procedure is called a biopsy; the tissue removed may consist of a part of the primary neoplasm or of a metastatic nodule. Biopsy of the original lesion should include normal as well as abnormal tissue in one piece so that the transition between the two can be studied. Serous effusions due to malignant disease may contain a sediment which will reveal cancer cells. Aspiration biopsy, which requires only a large needle, is an alternative method and may be

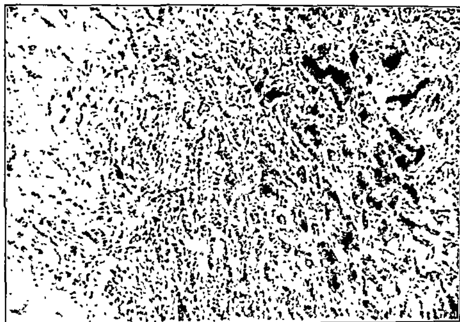


Fig. 2. Photomicrograph showing the invasive character of malignant disease. The microscopic section was taken from a carcinoma of the breast which had been removed surgically. Note the penetration of the strands of cancer cells through the fibrous stroma with no evidence of encapsulation or limitation.

used in certain patients, although it appears that this procedure may, at times, spread the disease.

The histological evidences of malignancy are as follows:

(*a*) *Abnormal cells,* more or less undifferentiated, even though growing in a form somewhat characteristic of the original tissue, are present. Nuclei stain more deeply and cytoplasm is more abundant.

(*b*) The growth is characteristically *invasive,* breaking through the normal tissue boundaries and extending into adjacent structures (Fig. 2).

(*c*) Rapid growth is often evinced by numerous *mitotic figures* and abnormally formed cells.

(*d*) The *fibrous tissue reaction* of the body to the tumor is sometimes very marked, especially in the so-called scirrhous type in which the intense fibrous tissue wall is formed presumably in an attempt to envelop and destroy the malignant cells. In rare instances this seems to have been achieved, since thorough search of the fibrosed tissue reveals few if any cancer cells. Such observations suggest the existence of a resistance on the part of the body to cancer.

(*e*) Attempts have been made to estimate the degree of malignancy by studying, more or less quantitatively, the above features of the cancer cells. Thus Broders has divided cancer into four arbitrary groups of malignancy, Types I, II, III, and IV, depending upon their histological features. While helpful in prognosis in certain cases, such histologic predictions are often inaccurate. The degree of malignancy is estimated with accuracy only by observing the clinical behavior of the growth.

Types of Malignant Disease. Malignant neoplasms are customarily divided into two groups, depending upon whether they originate from connective (mesodermal) or epithelial (ectodermal) tissue, although, as will be seen, this division is not absolute, for some tumors contain both types of cells. Occasionally it may be difficult to determine whether a neoplasm has originated from mesoderm or ectoderm. Ordinarily, however, this classification is fairly exact. The term *sarcoma* is applied to malignant tumors arising from mesoderm, i.e., fibrous tissue, cartilage, bone, fat, blood vessels, lymph tissue, and muscle, whereas *carcinoma* includes tumors of ectodermal or epithelial origin, i.e., skin, mucous membrane, liver, kidney, pancreas, and thyroid. There are certain other distinguishing features which separate sarcoma from carcinoma. Sarcoma, in general, is

bulky and soft, tends to remain demarcated, but grows rapidly along a vascular framework, often to great size, and is locally destructive. Notable exceptions are the hard osteosarcoma and some fibrosarcomas. Areas of hemorrhage, degeneration, and necrosis within the tumor are common. Sarcoma tends to break into blood vessels and metastasizes first to the lungs and later to other organs. Carcinoma, in general, grows more slowly but may metastasize when the tumor is small, first to the regional lymph nodes, then to the liver, lungs, bone, and so forth, by way of the blood stream; occasionally the reverse may be true. Originating from epithelial surfaces it is, of course, much more susceptible to ulceration and infection than sarcoma.

Treatment. Regardless of type, the general principles of curative cancer therapy are based on the eradication of *all* malignant cells. This eradication may be achieved (1) by surgical excision, (2) by destruction with radiotherapy and chemotherapy, or (3) by a combination of both. When cure cannot be hoped for, effective palliation is the secondary objective. The details of cancer therapy vary widely. The general principles are discussed in the next chapter.

I. Carcinoma. *Malignant tumors of epithelial origin may arise from the skin or mucous membranes or from glandular tissue such as the breast, prostate, colon, ovary, and thyroid. The term adenocarcinoma is used when the growth assumes an acinose form or originates from glandular tissue. When the tumor takes the form of a polyp or papilloma it may be called papillary carcinoma. The hard center of breast carcinoma with its lateral invading extensions suggested to Galen the appearance of a crab, hence its Latin equivalent, cancer.

1. CARCINOMA OF THE SKIN AND SQUAMOUS MUCOUS MEMBRANES. These carcinomas comprise (*a*) squamous cell, (*b*) basal cell, and (*c*) malignant melanoma. A fourth

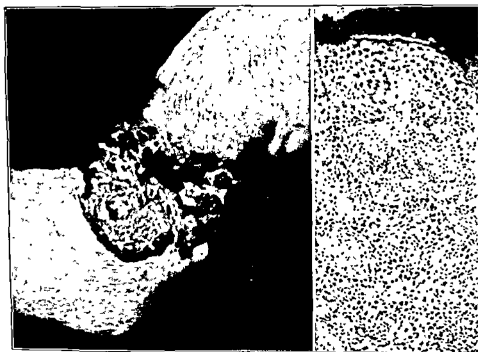


FIG. 3. Squamous cell carcinoma of the arm in an old ulcer (Marjolin's ulcer). The patient was an 80-year-old farmer who developed an ulcer which persisted following an injury 57 years previously. One year before admission a fungating growth developed at the site of the ulcer which grew steadily to the size shown in the illustration. Pain also developed and grew steadily worse. This represents the hypertropic type of squamous cell carcinoma and is of a relatively low degree of malignancy. The photomicrograph is from a biopsy specimen; note the extensive growth of squamous epithelium and the lymphocytic infiltration. Treatment in this type of tumor consists of wide local excision and the application of a skin graft to cover the defect; regional lymph nodes are also excised; occasionally amputation is indicated.



Fig. 4. Squamous cell carcinoma of the ear. In lesions of this type, resection of the major part of the ear is necessary; if the cervical nodes are involved, a radical neck dissection is also necessary.

type (*d*), Paget's disease of the nipple, is also included here because it starts as a skin lesion though it is always associated with or leads to adenocarcinoma of the breast. The term epithelioma is commonly applied to either the squamous cell or basal cell tumors of the skin, or collectively to both.

(*a*) *Squamous cell carcinoma.* This type occurs not only in the skin (Figs. 3, 4) but also in mucous membranes composed of squamous cells (buccal and genitourinary orifices). It also occurs at times by metaplasia from mucous membranes not normally composed of squamous cells, i.e., bronchus and gallbladder.

In the *skin,* it is most common in the head and neck, but it is prone to develop at the site of an old scar following a burn or extensive trauma (Marjolin's ulcer). Indeed, a previous lesion of some kind or a source of chronic irritation seems a common precursor of squamous cell carcinoma wherever its site. Males are more frequently affected than females (2:1). The growth takes one of two general forms, the papillary or the ulcerating type. The former is much less malignant and grows slowly as a cauliflower projection from the skin and metastasizes late. The ulcerating form is invasive, spreads rapidly, and metastasizes to the neighboring lymph nodes early. The edge is raised and indurated; the base is deep and bleeds easily. The ulcerative type is to be distinguished, however, from basal cell carcinoma which is described later.

In the *buccal cavity,* squamous cell carcinoma attacks the lip (Fig. 5), jaws, tongue, or pharynx. It affects males predominantly (5:1), but it is not a common lesion, accounting (with the skin) for but 6 per cent of malignant disease. As in the skin, previous lesions and chronic irritation in the buccal mucosa are frequent precursors of cancer. *Leukoplakia* is a common predisposing lesion which is said, in turn, to be associated with excessive use of tobacco and with syphilis. Leukoplakia is manifested as a whitish area in the mucosa of the borders of the tongue or lip, of a tough, leathery consistency, having a tendency in its later stages to become the site of fissures or ulceration. Microscopically,



Fig. 5. Squamous cell carcinoma in the lower lip. Verified by microscopic examination of a biopsy removed from the edge of the lesion.



Fig. 6. Leukoplakia. Photomicrograph from a section of a small white elevated area removed from the inner side of the patient's cheek. Note the hyperplasia of the keratin layer and the characteristic lymphoid infiltration and follicle formation just beneath the epidermis. This lesion is definitely a precursor of squamous cell carcinoma, and total removal is generally indicated.

the lesion consists of a proliferation of the outer squamous cell layers (Fig. 6). Other predisposing lesions are fissures of the lip, herpetic ulcers which do not heal, ulcers at the site of sharp teeth or dental appliances, and inflammation due to the prolonged use of pipes. Years ago, syphilis was said to be associated etiologically with carcinoma of the mouth but, apart from causing leukoplakia, such a theory is not tenable. As in the skin, two broad forms are distinguished clinically: the hard, ulcerating type and the soft, cauliflower or papillary type. In the lip, squamous cell cancer commonly attacks the lower lip. The ulcer is characteristic with a raised, indurated edge but may be flat and grow slowly, and seem to heal over in its less malignant form. Metastases occur to the cervical nodes which become enlarged; enlarged nodes, however, may be due to infection and not to cancerous invasion. Chancre of the lip may be mistaken for carcinoma, although the history, its short duration, and early involvement of lymph nodes should point to chancre. The finding of spirochetes in the discharge by darkfield illumination will establish the diagnosis of chancre and is of obvious importance.

In the *tongue, jaws, and pharynx,* carcinoma also presents a characteristic appearance, but occasionally is detected only by careful search (Fig. 7). Patients are usually aware of lesions in the mouth regardless of their characteristics (*13*). If in the cancer



Fig. 7. Squamous cell carcinoma of the tongue. Diagnosis was verified by microscopic examination of a biopsy specimen. The lesion, apparently of one year's duration in a 45-year-old male, disappeared after local radium treatment; a regional lymph node (neck) dissection was also carried out. Some surgeons prefer to completely excise the primary lesion when feasible.



Fig. 8. Basal cell carcinoma. The lesion started as a tiny "pimple" several months previously; the patient was a 65-year-old male. Entire lesion was excised and the wound closed by primary suture; healing was prompt and permanent.

age, they should be taught to have such lesions investigated. Pain, salivation, and hemorrhage are generally present only in the later stages. Dentists frequently see such lesions first. In the deeper recesses of the buccal cavity, especially the larynx, carcinoma is frequently unsuspected until such symptoms as hoarseness, bleeding, or, in some instances, cervical metastases occur. In the antrum, carcinoma is rare.

Treatment of squamous cell carcinoma of the skin and buccal mucosa first of all should be directed at the detection and treatment of the predisposing lesions which have been already mentioned. If doubt exists as to the nature of a chronic lesion, excision and mi-

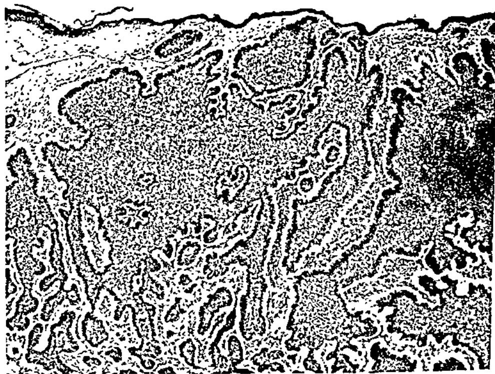


Fig. 9. Photomicrograph of basal cell carcinoma. This patient was a man, aged 69, who stated a small "sore" developed on the side of the nose and gradually grew; it bled readily and frequently. Because of neglect it was nearly 2 cm. in diameter and required resection of so much tissue that a sliding skin flap was required for closure.

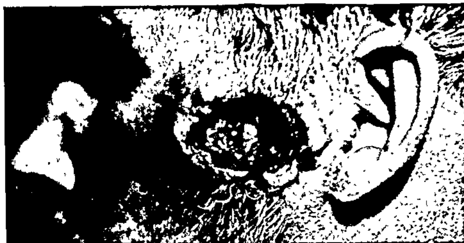


Fig. 10. Basal cell carcinoma of the face. The patient had submitted to improper treatment by the application of a "cancer paste" for several weeks. Note that the central portion of the lesion was destroyed at least in part, but the tumor at the edges is growing very actively. Radiotherapy is now being used.

croscopic section should be made. Destruction of such lesions is less advisable since it eliminates the opportunity for histologic study. There are two accepted methods of treating carcinoma of the buccal cavity. Many surgeons prefer wide excision of the lesion with bloc (neck) dissection of the regional lymph nodes. Other surgeons favor x-ray or radium therapy; combination of surgery and radiation may be used.

In the other orifices containing squamous cells, namely, the *genital* and *urinary* openings, cancer is also relatively easy to detect early, because the surface involved can be inspected and the lesion seen. In the bladder this requires a cystoscope, but in the cervix merely a speculum. Very important is detection of cancer of the female generative organs, since carcinoma of the cervix and uterus alone constitute 14 per cent of all malignant disease. The symptoms which should direct attention to such lesions are few. Abnormal bleeding, even though slight in amount, should always warrant an examination. Further discussion will be found in later chapters.

(*b*) *Basal Cell Carcinoma* (*Rodent or Jacob's Ulcer*). This carcinoma is most common on the face (Figs. 8, 9) and neck where it slowly invades the adjacent skin and underlying structures, although it practically never metastasizes. In rare instances it may arise in the skin of other regions, such as the legs, perineum, and upper chest wall. Basal cell carcinoma is a common disease in older persons and is frequently seen at a site of chronic irritation. Chronic exposure to the elements predisposes to its occurrence, hence its frequency in farmers. Basal cell carcinoma starts as a smooth nodule in the skin, then grows in size, and eventually breaks down in the center giving rise to an ulcer whose edges are elevated, indurated, nodular, and present a characteristic pearly appearance. The base is apt to be shallow, fibrotic, and covered with pale granulations. The ulcer progresses in size, but advanced cases with extensive destruction of tissue are rarely seen at the present time because adequate early treatment is so generally used and effective. Radiation (basal-cell carcinomas are among the most radiosensitive tumors), excision, or local destruction by cautery is curative. However, unless completely removed or destroyed, the growth recurs at an increased rate (Fig. 10).

(*c*) *Malignant Melanoma* (*Melanoblastoma, Chromatophoroma*). This carcinoma is a special form of malignant tumor of the skin arising in a mole (Fig. 11). The term melanoma is applied to tumors containing melanin, a brownish black pigment; melanomas may be malignant or benign. The benign type is discussed on page 418. Opinions differ as to whether malignant melanomas are of ectodermal or mesodermal origin; hence the term melanosarcoma, as well as melanocarcinoma, is often used.

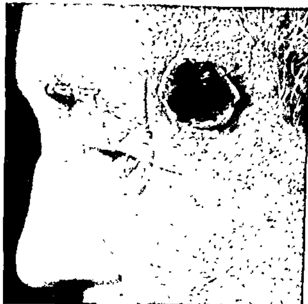


Fig. 11. Malignant melanoma. This lesion started as a small "pimple" eight months previously. Melanomas in this location are associated with a poor prognosis.

The retina of the eye, which contains the pigmented cells, is also a source of the neoplasm; however, melanomas in this location are surprisingly mild insofar as the five-year survival following enucleation of the eye is about 50 per cent. The disease is often very malignant, but in some cases many years may elapse between apparent successful removal of a primary growth and death from distant metastases which are rapid and widespread. The factors responsible for the prolonged inhibition of spread in such cases are unknown.

Metastasis may occur by way of the lymphatics (Fig. 12) or the blood stream. These tumors may be encountered at any age, are fairly common in young adults, but rarely indeed are found before puberty. It is important to remove moles which have a tendency to become malignant. It is obviously impracticable to remove all moles, but those subject to continued irritation should be excised since irritation is prone to provoke the malignant change. It is important especially to remove moles on the head and feet since those areas are the most frequent sites of the initial lesion of malignant melanoma. Any mole which exhibits sudden growth or bleeds without sufficient provocation should also be excised. If the mole shows microscopic evidence of malignancy the regional lymph nodes should be removed. Fortunately, malignant melanoma is a rare disease. It should be mentioned that occasionally nonpigmented moles undergo malignant change.

Malignant melanomas are much less vicious than generally considered, particularly if proper treatment—i.e., wide excision with radical resection of lymph nodes (even *though no nodes are palpable)*—is carried out. For example, in their experience with over 1,000 cases, Pack and associates (14) report a five-year survival rate of 14.1 per cent in patients with metastases to lymph nodes and 40.5 per cent in patients without metastases. In a study made by Booher and Pack (15) of all the melanoma patients seen at the Memorial Cancer Center, 16.5 per cent of the melanomas were located on the feet and hands. In patients having groin dissection (for melanoma on the lower extremity) without clinical or microscopic evidence of nodal metastases, the five-year survival rate was 40 per cent compared with 20 per cent if nodal metastases were present. The over-all salvage rate (five-year survival) for melanoma of the hand was 40 per cent but only 20.7 per cent for subungual melanoma. In 107 cases, Meyer (16) reports a five-year survival rate of 51 per cent. He advises prophylactic node resection as well as radical operation when nodes are palpable; 28 per cent of patients diagnosed as having negative nodes in his series actually were positive when examined in the surgical pathology room.

(*d*) *Paget's Disease of the Nipple*. This is a specific disease of the epithelium of and surrounding the nipple of the breast which ultimately develops into or is in some way associated with carcinoma. It starts as an exfoliating dermatitis or eczema which *does not* heal. The carcinoma is a typical adenocarcinoma of the breast whose histologic relation to the changes in the skin remains unestablished, though clinically the one seems to follow the other rather definitely. As a matter of *clinical practice any chronic dermatitis* of the nipple should be examined at frequent intervals; if it responds to local treatment and heals, as most cases of dermatitis do, the lesion is benign. If it does not heal and the patient is in the cancer age, operation is indicated (17) (see also Chapter 35).

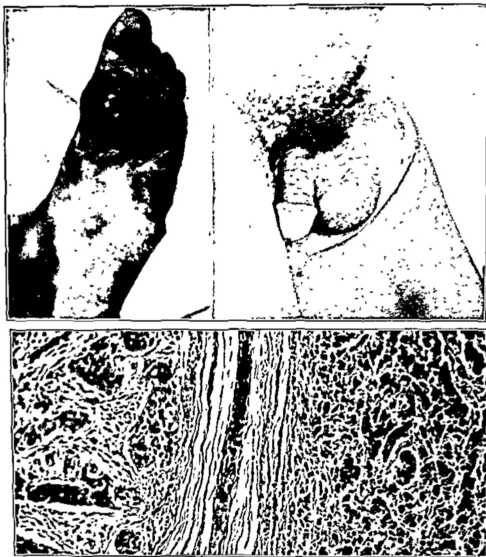


Fig. 12. Malignant melanoma. The course was rapidly fatal. The patient was a 45-year-old Negro; however, this type of cancer is relatively rare in the Negro race. The lesion started under the ball of the foot as a callus which the patient pared repeatedly. Rapid growth occurred during the past six months and a mass appeared in the groin. The photo shows the primary lesion in the foot and the metastasis in the regional (femoral) nodes. Death occurred one week later; autopsy revealed widespread metastases. The photomicrograph shows malignant cells both with and without the melanin pigment.

2. Carcinoma of Glandular Origin. This group is by far the largest and comprises most of the other epithelial malignant tumors (Fig. 13). The malignant cells usually assume the form of acini, rosets, or alveoli. Occasionally they are arranged in cords of cells. Other variations are also described. *Scirrhus* is a term which is applied to that type of cancer marked by fibrosis in and around the tumor as if the defense mechanisms of the body were trying to strangle the cancer. *Medullary (encephaloid) carcinoma* is a term applied to a soft, bulky tumor composed largely of cancer cells with very little associated fibrosis. *Colloid carcinoma* refers to tumors arising from mucous glands or to the growths which produce a great deal of mucoid material, visible grossly or microscopically. *Colloid* is found in cancer of the breast, stomach, and colon. When the cells take the form of acini, the term used is *adenocarcinoma*. These tumors may arise from either the secreting glandular cells or from the cells lining the ducts. Detailed discussions of glandular

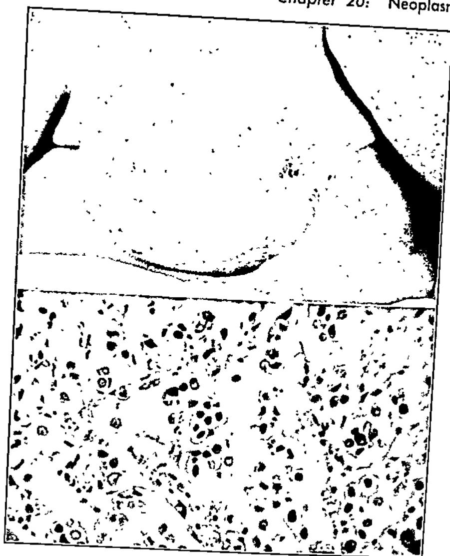


Fig. 13. Carcinoma of the breast of "low" malignancy. Note the retraction or puckered appearance of the skin over the lesion which was observed during a routine examination. The patient, aged 80, had been admitted to the medical ward because of severe hypertension; she claimed that the breast tumor had been present for 10 years. It was observed for three more years without any appreciable change. The photomicrograph was obtained from the specimen which was removed at autopsy when the patient died of cardiac disease. This represents a very slowly growing, almost benign, type of carcinoma and is, of course, unusual; it is of importance to note, however, that the microscopic appearance of the lesion gives very little indication of this characteristic This illustrates how misleading the "grading" of carcinoma may be when based on microscopic examination alone.

carcinoma will be found under the descriptions of diseases of the individual organs.

3. Miscellaneous Carcinomas. There are other carcinomas of miscellaneous types which are difficult to classify under a single designation. These tumors include hypernephroma, metaplastic neoplasms of the lung, and malignant teratomas, and will be discussed under the various organs affected. *Carcinoid* is a term applied to tumors which may occur anywhere in the gastrointestinal tract, most commonly in the appendix (see p. 760) but occasionally in the ileum. They are usually localized and benign but may sometimes become malignant and metastasize to lymph nodes, rarely elsewhere. Removal of the primary and the involved lymph nodes is almost always curative. The presence of serotonin metabolites (18) in the urine may be helpful in making the diagnosis.

II. Sarcoma. Sarcoma is less common than carcinoma, comprising but 3.5 per cent of all malignant tumors. It may develop wherever mesodermal tissue cells are present or grow from pre-existing benign tumors which are thus said to undergo "sarcomatous degenera-

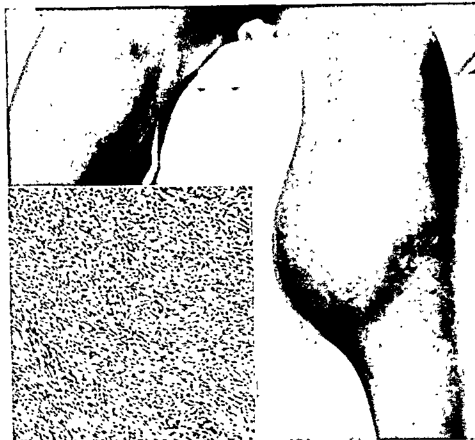


Fig. 14. Fibrosarcoma of the left leg. The patient, a 19-year-old Negro girl, first noted a swelling a year before admission; growth was rapid. In spite of amputation, pulmonary metastases occurred and the patient died six months later. The insert is a photomicrograph of the tumor and shows the undifferentiated spindle cell growth; there is less intercellular material than occurs in the more benign type of fibrosarcoma shown in Figure 15.

tion." The terms *spindle cell, round cell,* and *giant cell sarcoma* are histologically descriptive, but they do not indicate from which mesodermal element the tumor arises. To designate the exact tissue of origin the terms *fibrosarcoma, liposarcoma,* and *osteosarcoma* are used. In some instances, the histologic appearance of the tumor indicates its cell of origin. In many cases, however, this may be impossible to detect, especially when the growth is composed entirely of small or large round cells, although round cell sarcoma is ordinarily of lymphoid origin. Regardless of their microscopic appearance, the gross clinical manifestations as mentioned previously are fairly distinctive. The tumor when soft is often mistaken for a hematoma, an abscess (tenderness may be present) aneurysm, lipoma, or fibroma. With a large aspirating needle one is sometimes able to obtain a sufficient amount of tissue for microscopical study, although an actual biopsy is usually preferable.

Although no classification is entirely satisfactory, the various kinds of sarcoma may be most simply divided into 1. spindle cell (fibroblastic) sarcoma; 2. sarcoma of bone, and 3. round cell (lymphogenous) sarcoma. To this may be added 4. a small group of miscellaneous sarcomas, most of which are very rare.

1. Fibrosarcoma (Fibroblastic or Spindle Cell Sarcoma). *This tumor represents the most common type of sarcoma and is encountered chiefly in the subcutaneous and submucous tissue, the fascia, intermuscular septums, periosteum, and also in parenchymatous organs (Fig. 14). The size, consistency, and rate of growth vary greatly. Histologically, the cells are arranged in whorls of spindle cells which resemble fusiform fibro-

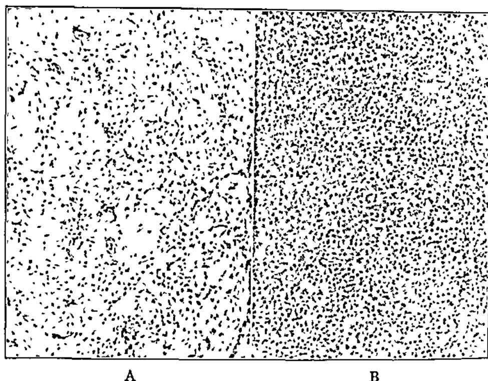


Fig. 15. Myxosarcoma, a more benign type of fibrosarcoma. A slowly growing tumor of the thigh in a male, aged 50, was excised three times during the course of six years because of recurrence. The photomicrographs are both from the tumor removed at the last operation; a fatal outcome several months later was due to widespread metastases. A, histologic appearance of a typical myxosarcoma, quite similar to that noted in the original tumor; B, this appearance was noted but a few millimeters away on the same slide as that of A; it shows a more cellular phase of tumor growth which is characteristic of this lesion whenever it develops increased malignant tendencies.

blasts and which may be either large or small. Because of their arrangement around the arteries they often seem to arise from the adventitial cells of the blood vessels. When they are present in the thigh, which is a frequent site, the tumor is bulky and has a tendency to local mucoid degeneration. When the entire tumor contains mucoid material it may be spoken of as *myxosarcoma*. It grows slowly, is prone to recur after excision, is not apt to metastasize, but is nevertheless usually fatal often because of a change in its cell type (Fig. 15).

Fibrosarcoma is seen early only when it appears near the surface of the skin. Though it may seem to be a fibroma grossly, a histologic diagnosis of sarcoma can be readily made and, of course, calls for wide excision. Fibrosarcoma usually grows rapidly but produces few symptoms until a large size is attained. Clinical manifestations are due to pressure of the tumor on adjacent structures. More often its size alone is the only complaint. Treatment consists of complete and wide excision, removing all the malignant tissue. Recurrence, however, is common; in the relatively benign myxosarcoma careful but wider excision of the recurrent tumors will be necessary. However, amputation may be indicated in the more malignant types of myxosarcoma when the tumor is in an extremity. Occasionally the tumor grows so rapidly that death occurs from metastases, particularly to the lungs, regardless of therapy. Other types of sarcomas, fibroblastic in origin, are occasionally found in the esophagus, stomach, intestine, uterus, ovary, and other organs, where they produce special symptoms dependent upon their location and may exhibit special and unusual microscopic features.

2. Bone Sarcoma. Probably because it is a rather rare tumor (1 per cent of all malignant lesions), bone sarcoma has long been a source of confusion because it produces a great variety of clinical, roentgenologic and histologic manifestations (Fig. 16). In order to recognize primary sarcoma of bone it is

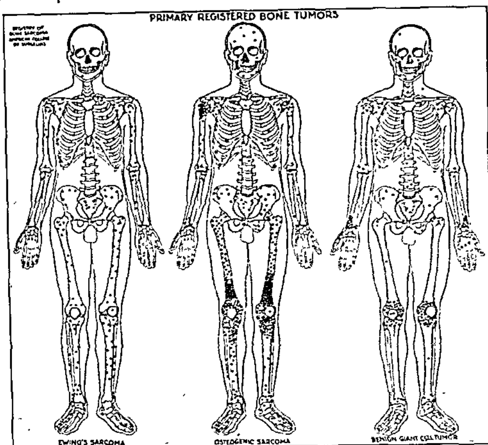


Fig. 16. Distribution of primary bone tumors. Note that the region of the knee is the most frequent site for osteogenic sarcoma. (From the Bull. Am. Coll. Surg.)

useful to realize that other bone lesions simulate it. In surveying these various bone diseases, one must distinguish the 1. malignant neoplasms which are not primary, i.e., carcinomas which have metastasized to bone from a focus elsewhere; 2. the group of true neoplasms of bone which are benign, particularly the giant cell tumor; and 3. the other diseases, inflammatory and metabolic, which simulate bone tumors.

Metastatic carcinoma to bone, the first group, is statistically important because of its frequency. Common clinical manifestations are pain, swelling, and spontaneous (pathologic) fractures. Occasionally, these lesions are the first intimation of disease, the primary focus remaining occult. The roentgenogram reveals bone destruction often described as having a "moth-eaten" appearance (Fig. 17), although in other instances there are areas of increased density simulating new bone formation. Of the *benign bone neoplasms,* giant cell tumor is most frequently a source of difficulty in diagnosis; these lesions are discussed further on page 408. Of the *inflammatory and metabolic diseases* of bone which are confusing, osteomyelitis is perhaps the most important, especially in differentiating from Ewing's tumor. These lesions are described in Chapter 24.

The classification within the group of true primary bone sarcoma also offers considerable difficulty, particularly in regard to the histologic appearance and pathogenesis of the various types. For this reason, no attempt will be made to distinguish, e.g., between those arising from cartilage and from bone, those which destroy or form bone, and those which are central, subperiosteal, or periosteal.

(*a*) *Osteogenic Sarcoma.* The term "osteogenic sarcoma," first used by Ewing, refers only to sarcoma originating in bone and must not be confused with the same term used to imply a sarcoma which forms bone (in con-



Fig. 17. Metastatic carcinoma in the skull arising from a primary (bronchiogenic) carcinoma of the lung.

trast to osteolytic sarcoma which destroys bone). Actually both bone destruction and bone formation may occur and is, of course, extremely important roentgenologically.

Clinical features of osteogenic sarcoma are usually distinctive. It is a tumor of adolescence, 50 per cent occurring in the second decade of life during which normal bone growth is most active. Moreover, 72 per cent occur in the lower extremity and of these 82 per cent are about the knee. They start at the end of the bone near the epiphysis (Fig. 18). The most important manifestation is pain, which precedes the appearance of the tumor and is severe and persistent. Such pain, when it develops in the long bones of the young adult, should always arouse the suspicion of bone sarcoma. The significance of trauma, though of great medicolegal importance, is questionable clinically; there is no evidence that trauma has etiologic significance. The swelling is slight at first but in neglected cases is characteristic, exhibiting a dusky hyperemia and often numerous dilated veins in the overlying skin. Local tenderness may be present, but on palpation the tumor will be hard and firm. Systemic manifestations are usually absent in this tumor. In some instances, where the tumor is near a joint, the signs and symptoms suggest a clinical diagnosis of arthritis and treatment for this condition is erroneously instituted.

Diagnosis is often aided by two procedures: x-ray and biopsy. The roentgenogram may be characteristic but is often equivocal. Both lytic and blastic processes are evident though one or the other predominates. The so-called "sun-ray" picture is usually pathognomonic but is not frequently observed. Adequate biopsy should be performed wherever possible to establish the correct diagnosis. This procedure is not easy in the case of malignant bone tumors as the surgeon too frequently removes overlying compressed tissue about the tumor and not portions of the neoplasm itself.

Treatment consists of operation or radiotherapy or a combination of both. Surgery may be either conservative (resection) or radical (amputation). Although "cure" is obtained only in a minority of cases (15 to 20 per cent), the surgeon aims to prolong life as much as possible and to ensure the comfort of the patient. When the tumor appears relatively small and has not perforated the overlying periosteum, most surgeons are reasonably conservative concerning amputation, insofar as they tend to resort to resection and bone graft with radiotherapy whenever local resection is possible. However, on many occasions local resection will be impossible, and amputation is the only hope of a cure.

(*b*) *Ewing's Sarcoma.* This neoplasm is relatively rare, comprising less than 10 per

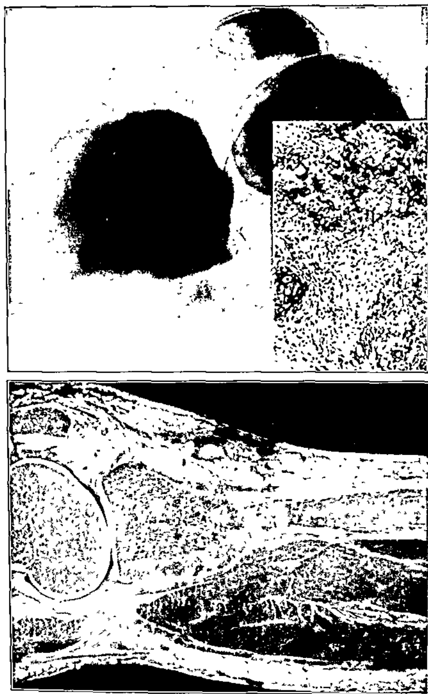


Fig. 18. Osteogenic sarcoma of the tibia. The patient was an 18-year-old boy. There was a history of trauma several weeks before the onset of a continuous ache which antedated the appearance of the swelling by two weeks. Swelling increased rapidly for six weeks before operation; a mid-thigh amputation was performed. The x-ray film shows a suggestive "sun-ray" effect; the lower photograph represents a longitudinal section of the amputated leg and shows the destructive process in the upper end of the tibia. The insert is a photomicrograph which shows malignant cells forming bone.

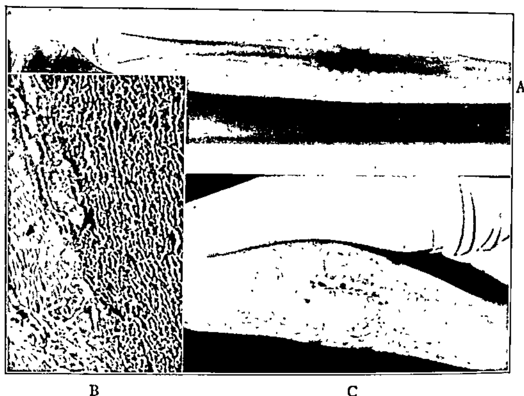


Fig. 19. Ewing tumor of the fibula. The patient was a 12-year-old boy. There was a history of swelling of the calf, and pain of four months' duration. A, x-ray on admission; note the location of the lesion in the center of the shaft and the "onion peel" appearance above and below the central portion of the tumor. B, photomicrograph of biopsy which confirmed the x-ray diagnosis; note the lymphoid character of the tumor invading the adjacent stroma. C, photograph of the leg one month later, following radiotherapy. Death followed within a year.

cent of all bone sarcomas; more than half are seen in children between the ages of 6 and 15 years. It originates as a small round cell tumor resembling lymphosarcoma, probably from lymphatic channels within the cortex, but produces pronounced bone changes (Fig. 19). Unlike osteogenic sarcoma, it attacks the shaft rather than the end of the bone. Another characteristic of Ewing's sarcoma is that it metastasizes to the other bones as well as to the lungs. Clinically, pain is apt to occur in attacks and is usually preceded by trauma. Systemic manifestations of fever and leukocytosis, as well as local tenderness, often lead to a suspicion of osteomyelitis. Roentgenograms are often diagnostic because the tumor is located in the intracortical part of the shaft and also because the so-called "onion-peel" and "sun-burst" appearance is sometimes present. Treatment is that of osteogenic sarcoma. Immediate response to x-ray therapy characterizes this group of neoplasms.

(c) *Myeloma.* This is even more rare, occurs mostly in middle and advanced age, and is manifested by rheumatic pain and skeletal deformities in advanced stages. Spontaneous fractures, most often in the ribs, are frequent. The common histologic type is characterized by large plasma cells; less frequently, the type of cell consists of a myeloblast. Roentgenograms show multiple "punched-out" areas; between 50 and 75 per cent show Bence-Jones proteinuria. All cases are fatal in about two years. Treatment is symptomatic, x-ray often alleviating the pain.

(d) *Unclassified Sarcoma.* In this final group are placed two tumors—angioendothelioma and extraperiosteal sarcoma of bone. The first is extremely rare and presents the same diagnostic and therapeutic problem as osteogenic sarcoma; it is described separately largely because of its peculiar histologic appearance. The second tumor is in reality no bone sarcoma at all, but a fibrosarcoma of the periosteum or adjacent fascial planes, and behaves and is treated as other fascial sarcoma. It may produce bone changes but only by pressure from without.

3. SARCOMA OF LYMPHOID TISSUE (MALIGNANT LYMPHOMA). Though essentially a round cell tumor, this type may be classified, according to Ewing, into at least four groups. This division is largely arbitrary, however, since the cell of origin is not always known. Nevertheless, these tumors have the clinical features of malignancy and seem to arise from, or at least to involve, the lymph nodes primarily. Many of these lesions respond to anticancer agents, which is very useful, particularly in the lesions which are not amenable to surgery or radiation. The polyfunctional alkylating agents—e.g., nitrogen mustard, triethylenethiophosphoramide (thio-TEPA) and triethylenemelamine (TEM)—and numerous antimetabolites—e.g., 6-mercaptopurine and aminopterin—have been used in these lesions, often with satisfactory regression (19), although no cures have as yet been achieved.

(*a*) *Simple Lymphoma* (*Lymphadenoma, Hyperplastic Lymphadenitis*). This type, though histologically a benign and usually inflammatory enlargement of lymph nodes, is mentioned here because it sometimes presents difficulty in microscopic diagnosis. This becomes evident when the nodes persist, grow, and eventually cause death (Ewing). Subsequent study may show that they bear a relation to the other obvious malignant tumors of lymph nodes.

(*b*) *Leukemia.* Though a neoplasm of the blood forming cells, leukemia is included here because the lymph nodes are involved in the disease, regardless of whether the leukemia is of the lymphatic type or of the myelogenous type. The nodes are usually discrete, although when they are large they soon coalesce. The spleen is often enlarged. Blood examinations make the diagnosis, except in certain cases when there may be no leukocytosis (aleukemic leukemia). Excision of a node will reveal a microscopic picture which is characteristic. Treatment with intravenous injections of nitrogen mustard or of radioactive phosphorus is often effective. Deposits of lymphogenous or myelogenous cells are sometimes seen at other sites, including the skin (leukemia cutis). A greenish tumor of a leukemic type which may occur in the skull, vertebrae, and ribs is called *chloroma* and, curiously enough, appears now to have become almost extinct.

(*c*) *Hodgkin's Disease.* This is a malignant disease *involving the lymphatic system,* particularly the lymph nodes; it is manifested by progressive enlargement of the lymph nodes most frequently in the cervical region but also in the mediastinum and elsewhere; the disease is often associated with fever, anemia, and other blood changes. The enlarged nodes on microscopic section show a fairly characteristic hyperplastic picture upon which the diagnosis frequently depends (Fig. 20). Fibrosis of a diffuse nature is a constant finding but can be differentiated from that encountered in tuberculosis by the absence of necrosis and tubercles. Other features include the presence of numerous eosinophils and large multinucleated reticulum (Dorothy Reed) cells.

The disease is subject to much clinical variation; it is to some extent dependent upon the chain of nodes involved. In superficial locations, usually the cervical region, the individual nodes are palpable as discrete elastic masses, variable in size and not tender. The spleen is enlarged in over half the cases. X-ray may reveal enlargement of the mediastinal nodes; bone and skin involvement have been described. Generalized pruritis is said to be a frequent symptom at an early stage of the disease, the itching being due presumably to infiltration of the skin with lymphoid cells. Systemic symptoms may be absent; in some patients, on the other hand, high fever of the Pel-Epstein intermittent type and prostration develop. Changes in the white blood cells have been described but are frequently absent; eosinophilia and increase in the mononuclear cells of the blood, however, are often present and may be of diagnostic value. Anemia is sometimes severe and may require repeated transfusion. Radiotherapy and chemotherapy will cause temporary but usually rapid and complete regression of the enlarged nodes, although the course is usually downhill and death occurs after months or years from cachexia and anemia. A survival of over 20 years is shown in Figure 18, p. 611. When the disease is localized (i.e., without demonstrable metastases) in the neck or in any other operable site where radical resection is feasible, operation is indicated and

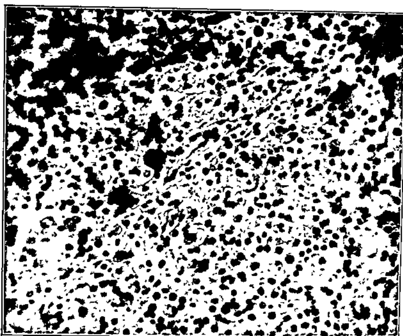


Fig. 20. Hodgkin's disease. Enlarged cervical nodes were observed three months before admission The photomicrograph is from a section of one of them which was excised for diagnosis. Note the characteristic multinucleated (Dorothy Reed) cell in the center of the field; many eosinophils are also present. Death occurred one and one-half years later with enlargement of the spleen, mediastinal and mesenteric nodes. Radiotherapy was refused by the family because the patient, a 37-year-old male, was a mental defective.

will be followed by very favorable results (20).

(*d*) *Lymphosarcoma* (*Lymphoblastoma, Lymphocytoma*). This sarcoma is a true primary neoplasm of the lymphoid tissue. Lymphoid tissue is, of course, distributed more or less throughout the human body but is especially concentrated in the lymph nodes. At the present time it seems probable that this lymphoid tissue has its origin in a syncytial type of undifferentiated supporting cell which has the power of producing the so-called lymphocyte as well as the reticuloendothelial cell. Tumors arising from these two cell types may sometimes resemble each other and make classification extremely difficult. As a rule, however, they differ in microscopic and clinical characteristics just as normally they differ as to structure and function. For purposes of classification, therefore, we have two types of lymphosarcoma—the lymphocytic and the reticular cell.

1. Lymphocytic lymphosarcoma is a primary tumor, the type cell of which tends to resemble the lymphocyte. The chief symptoms are those produced by the local enlargement of groups of discrete nodes, without local tenderness or general symptoms, although a low grade fever and weakness may at times be present (Fig. 21). Cachexia is absent. Microscopically, the lymph node loses its normal architecture and in its place one sees masses of abnormal lymphocytes growing at random with a minimum of reticulum and usually no germinal centers. While this cell is extremely sensitive to irradiation at first, it eventually becomes resistant, and the life expectancy in this disease is rarely over two years except in unusual cases. In the later stages of this type of lymphosarcoma, fixed lymphoid tissue in many parts of the body may become involved or the tumor may metastasize as does any other sarcoma. At such times the lungs and heart are frequently involved.

2. Reticulum cell sarcoma is a primary tumor, the cell type of which tends to resemble the reticuloendothelial cell. It involves most frequently the lymph nodes of the neck, axilla, mediastinum, and abdomen. As this same cell type is dominant in Hodgkin's disease, the lymph node enlargement may often resemble this condition. In fact, there are some authorities who prefer not to separate

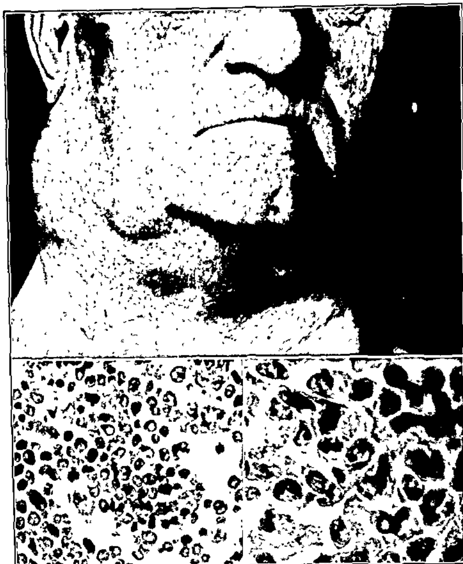


Fig. 21. Rapidly fatal lymphosarcoma. The patient was a 66-year-old man. The onset was only two and one-half months previously with a gradually increasing swelling of the neck and groin. At autopsy the nodes in the mediastinum and abdominal mesentery were also enlarged. Metastatic nodules were found in the lungs, kidney, and spleen. The low and high power photomicrographs show the histologic appearance of the cells.

the two diseases but rather to consider them as manifestations of the same fundamental disturbance. While at the onset the glands are generally discrete, there is a tendency toward coalescence during the later stages, giving clinical features not unlike those seen in certain types of exudative tuberculous lymphadenitis. The nodes are hard, not tender, and tend to remain local for a much longer period of time than does the lymphocytic type. Because of this act, local excision has at times been advocated and we have seen cases free from recurrence for a long period of time following this procedure. Recurrence does generally take place, however, along with involvement of other nodes and tissues. At this time, loss of weight is often seen and the picture becomes one of sarcomatous invasion. *Microscopically, the picture is that of* cells growing with an effort to form reticulum. The nucleus is large and vesicular and the cytoplasm abundant. Phagocytosis may even be observed in the slower growing types. Silver stains show a massive amount of reticulum.

Lymphosarcoma *may occur without obvi-*

ous involvement of lymph nodes. In such cases, the disease presents the clinical features of a localized neoplasm. For example, lymphosarcoma of the stomach is usually diagnosed as gastric cancer, yet has a relatively good prognosis. Since it affects the gastrointestinal tract in the small and large intestine and rectum, it seems to assume greater virulence.

4. MISCELLANEOUS SARCOMAS. Included under this heading are the following malignant growths of mesodermal origin: (*a*) *liposarcoma*, while rare, is a very malignant tumor with a rapidly fatal course, producing local and general metastases, especially to the lung. It is important to remove completely all lipomas, for they may, on rare occasions, harbor sarcomatous areas recognizable grossly as being very cellular and on section containing cells with only traces of fat. (*b*) *Rhabdomyosarcoma* are tumors of striated muscle which have become malignant. They are very rare. (*c*) *Thymoma* is a rather loosely used term to indicate a neoplasm involving the thymus. Many tumors in this region are really mediastinal lymphosarcoma. Tumors which involve the thymus primarily are quite rare; moreover, there is considerable dispute as to the histologic evidence of their origin.

III. Brain Tumors. Brain tumors are special neoplasms which are really difficult to classify. Many of them (gliomas) are of ectodermal origin; many, however, are really of uncertain origin. In many instances they produce death not by the usual means, i.e., metastasis, ulceration, cachexia, or wasting, but by virtue of their local effects on brain function and intracranial pressure. Some are benign in that they can be removed and the patient cured; others are malignant in the sense that they recur after removal, and continue to invade the brain tissue. Other brain tumors are metastatic from distant primary sites, especially from carcinoma of the lung. Consideration of these tumors belongs to the special field of brain surgery, and are discussed in Chapter 27. Details may be found in special publications (21, 22).

NEUROCYTOMA. This neurogenic tumor has general surgical interest because it occurs outside the brain and cord in the rich autonomic network of the posterior abdominal wall, producing a retroperitoneal tumor which causes symptoms by its size and by pressure on adjacent structures. Though malignant, and sometimes rapidly so, this neoplasm often responds dramatically to radiotherapy or even seems to disappear spontaneously. It is rather rare and simulates, even on microscopic section, other abdominal growths. A large percentage of these tumors are found in children. Other terms for neurocytoma are neuroblastoma, sympathicoblastoma, and so forth.

B. BENIGN NEOPLASMS

Unlike cancer, benign neoplasms grow to a limited size, do not metastasize, and in general are not fatal. A few are really not true neoplasms insofar as they result directly from irritative or inflammatory stimuli (keloid, clavus, cutaneous horn, and the like). The etiology of most benign tumors, however, is unknown except that some cellular stimulus to useless growth of this type must be present. Occasionally, the stimulus appears to be due to abnormal endocrine activity, particularly in the development of certain adenomas. The neoplastic change, though apparently different from that seen in cancer, may be of the same kind, but merely different in degree. Some benign tumors, moreover, have a malignant tendency insofar as they *recur* unless entirely removed. On rare occasions, benign tumors undergo spontaneous malignant changes, metastasize, and finally result in the death of the patient. It is possible, therefore, that when the cause of cancer is discovered one may also learn why benign tumors develop.

Like cancer, benign tumors may be classified into those arising from mesodermal and those arising from epithelial cells. However, it is clinically more useful to divide the benign neoplasms into seven groups depending upon the tissue of origin, regardless of its embryonic type.

I. Connective Tissue Origin. These neoplasms may be further classified into three subgroups: fibrous, fatty, and bone and cartilage tumors.

1. FIBROUS TISSUE TUMORS. Various in form and appearance, these neoplasms have in common a predominance of fibrous tissue on microscopic section. It will be recalled that this is, in fact, the microscopic charac-



Fig. 22. Keloids of typical appearance, both in Negroes. a, keloid at the site of a puncture for earrings; there was a history of considerable suppuration at the time the puncture was performed several months previously. b, this keloid formed at the site of a razor slash of the abdomen which had become infected and healed slowly.

teristic of the end stage of repair; scar tissue is nothing more than a mass of fibrous tissue. However, scar is distinguished from tumor by its inconspicuous size, i.e., though composed of the same tissue as a fibrous tissue tumor (fibroma), it is not large enough to be called a tumor. Sometimes, however, the deposition of scar is sufficiently large and conspicuous to be called a tumor; it is then called a keloid.

(*a*) *Keloid.* This neoplasm is in reality a fibroma that grows, however, only after a stimulus of injury which may be trivial, such as the puncture of an ear lobe for wearing earrings (Fig. 22). The demarcation between a normal scar and a keloid is inexact but depends largely on size. Other features of keloids are their tendency to form in Negros, their predilection for large granulating areas in which burns and severe suppuration have occurred, and their relative absence in clean, aseptic wounds which have healed without irritation. Though of considerable theoretical interest in wound healing and in their relation to neoplastic growth, keloids have a practical importance only when they become large or painful or when they are present over the face, neck, and arms, especially in young women. Excision is the treatment of choice, plus skin graft when the keloid is extensive. Radiotherapy has been disappointing.

(*b*) *Simple Fibroma.* This neoplasm is a circumscribed tumor arising spontaneously, anywhere in the body, but usually in the skin or subcutaneous tissue. When it occurs in the form of a papilloma, it is an ovoid tumor covered by skin or mucous membrane (Fig. 23), and attached by a thin stalk or pedicle. Fibroma, though it may consist entirely of fibrous tissue, is commonly associated with other mesodermal or epithelial elements and is therefore called lipofibroma, neurofibroma, adenofibroma, myofibroma, and so forth. Neurofibroma occurs in Recklinghausen's disease, which will be considered on page 410. When the cells in a fibroma have mucoid material between them, the tumor may



Fig. 23. Fibroma of the gum. This lesion started less than a year previously and grew rapidly. It was attached to the lateral portion of the gum on the upper jaw, with a relatively small stalk. It was removed without difficulty; prognosis is good.

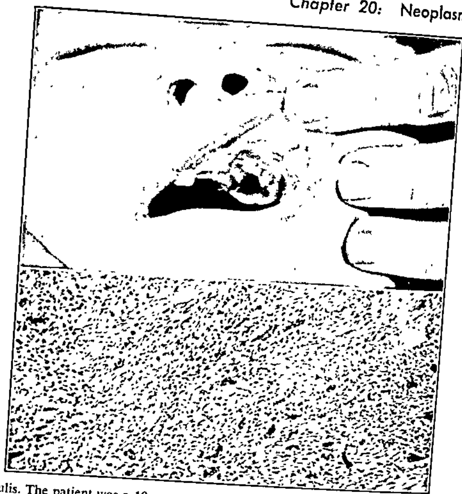


Fig. 24. Epulis. The patient was a 10-year-old girl. There was a history of an injury to the jaw before the onset of the tumor which was of two months' duration, growing slowly and bleeding occasionally. The insert is a photomicrograph of the excised tumor; note the numerous giant cells throughout the fibrous tissue stroma.

be spoken of as a *myxoma* or fibromyxoma. Many fibrous tumors which are soft contain myxomatous material. Certain small fibromas occur in the skin and become painful to the touch because of the presence of nerve fibers, though they are not true neurofibromas (see glomus tumors, p. 409). Treatment consists of excision when indicated. *Desmoid tumor* is a rare type of fibroma which originates from the fascial structures of the anterior abdominal wall, nearly always in women and in those who have borne children. While the tumor may sometimes contain cellular or myxomatous areas it is really a benign tumor, in spite of its tendency to recur after removal. Treatment consists of wide excision followed by adequate repair of the defect in the abdominal wall.

(*c*) *Epulis*. This is a name given to a fibroma (which often contains giant cells on microscopic section) arising from the portion of the gum which lines the submerged surface of the tooth (peridental membrane). It grows sometimes as a papilloma with the stalk attached to the gum at this point, but usually has a broad base and is expansile in its growth. It rarely grows to a large size, but recurs unless removed completely with a margin of normal gum tissue (Fig. 24). It is usually necessary to extract one or two teeth. In some instances sarcomatous changes have been observed.

(*d*) *Giant Cell Tumor*. This tumor, which is commonly found in the tendon sheaths and aponeuroses of the hands and feet, is a small fibroblastic neoplasm which contains giant cells. It is easily removed but tends to recur if not completely excised. Clinically it has no malignant tendencies, although it is occasionally spoken of as giant cell sarcoma largely because of its histologic appearance.

2. Fatty Tissue Tumors. There are but



Fig. 25. Lipoma of the arm and back. The lipoma on the arm has an unusually smooth outline, but the one on the lower left side of the back has the typical lobulated appearance. Both revealed a lobulated characteristic on palpation, less so on the arm.

two representatives in the group of fatty tissue tumors: the lipoma, which is common, and the xanthoma, which is rare.

(*a*) *Lipoma.* The lipoma is composed of normal fat cells or, at most, cells larger than normal, arranged in the form of lobules which may be large and few in number, or so multiple as to resemble a cluster of grapes. True lipomas are definitely delimited by the surrounding fibrous tissue which fits tightly around each of those lobules. Its most common sites are the subcutaneous tissues of the shoulders, back, upper arm, and buttocks, more frequently in obese individuals (Fig. 25). It has been found, however, in nearly every part of the body, including the pelvis, kidney, bone, and spinal cord. The tumor varies in size from that of a pea to that of a person's head. Its softness is a source of confusion to the novice, for it gives a sense of fluctuation which may lead to the diagnosis of a cyst or cold abscess. It may cause symptoms because of its size or cause pain by pressure on nerves. Treatment consists of excision which must be complete in order to prevent recurrence. A rare disease in obese individuals with multiple painful fatty tumors has been described by Dercum (adiposis dolorosa). Multiple subcutaneous lipomas may also occur and be associated with large accumulations of fat in the mesentery, palpable as an abdominal tumor.



Fig. 26. Osteochondroma. The location, as shown in the x-ray, is characteristic at the adductus tubercle of the femur. The patient was a nine-year-old boy. There was a history of injury to the knee which became "black and blue" at the site of a swelling noted by the mother. Operative excision was carried out; the diagnosis was confirmed microscopically.

(*b*) *Xanthoma*. The xanthoma, a rare tumor, may be single or multiple (xanthomatosis) and in the gross is yellow, hence the name. When the tumor is superficial, the color can be seen through the skin. Microscopically, it consists of foamy cells and, frequently, giant cells. The fat in the cells is composed of cholesterol and is supposed by some to represent a defect in cholesterol metabolism. These tumors may develop about the eyelids or joints or in tendon sheaths and are usually small. On rare occasions they are found in the ribs and cranium.

3. Bone and Cartilage Tumors. These tissues are conveniently considered together since they are frequently associated in the development of benign bone tumors. The tumors comprise five types.

(*a*) *Osteochondroma or Exostosis* (*Osteoma*). This is a common tumor, occurring most frequently near the ends of long bones, particularly at the distal end of the femur (Fig. 26). It arises, presumably, from misplaced cartilaginous tissue but consists primarily of bone. It produces no symptoms, often being noted accidentally in an x-ray film taken for another purpose. However, sometimes a mass is noticed; pain, when present, is more of an ache or discomfort. Occasionally a bursa forms over the tip of the tumor and may produce symptoms of bursitis when injured. Malignant changes may occur but only in persons over 30 years of age. Osteochondroma is most frequent in persons between 10 and 20 years of age. Roentgenologically, the tumor has a base of normal bone protruding through the periosteum, the tip of which is covered more or less completely by cartilage. If symptoms are present, excision, including a cuff of normal bone, is indicated. When noted in a person over 30 years of age, the possibility of malignant change should be borne in mind. Exostoses, when multiple, may have a pronounced hereditary tendency and other features. *Subungual exostosis* is a special variety of osteochondroma which grows under the nails of the fingers or toes where it may cause considerable pain and, by breaking through the skin, lead to secondary infection. Excision is usually indicated after infection, if present, has subsided.

(*b*) *Chondroma* (*Enchondroma*) or *Chondromyxoma*. This tumor is fairly common and, while it resembles the exostosis microscopically, it is a central tumor in contrast to osteochondroma, which is periosteal. It is most frequent in the phalanges (Fig. 27) of the hand or foot; it also is seen in the long bones, sternum (Fig. 28), and spine. It is only rarely multiple. The symptoms are those of swelling, tenderness, and pain. The larger tumors in the sternum and spine are prone to malignant change in that they are apt to recur and eventually to metastasize, unlike those appearing in the phalanges, which are more

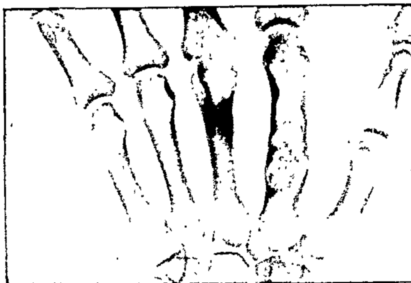


Fig. 27. Enchondroma of the second metacarpal. The patient was a 25-year-old machinist. The existence of the lesion was discovered only by x-ray, which was taken because the patient had a serious hand infection; a pyogenic arthritis with destruction of the articular cartilage of the third metacarpophalangeal joint can be clearly noted. No treatment was indicated for the enchondroma.

benign. Microscopically, the tumor contains fairly normal adult cartilage but grossly shows much gelatinous or myxomatous material. Roentgenologically, there is a translucent central area with thinning and expansion of the cortex. Unlike the osteochondroma, it contains no bone. It is the most common cause of central bone destruction in the phalanges (see Fig. 27). Though rare in the long bones, its x-ray appearance is similar to bone cyst or benign giant cell tumor. Treatment, when indicated because of pain or swelling, consists of thorough excision.

(*c*) *Bone Cyst.* The bone cyst is different from osteitis fibrosa cystica in that it is solitary, whereas the latter term implies multiple lesions. Bone cyst is most frequent in the upper humerus (Fig. 29), tibia, and femur. It is most common in children under 15 years of age, occasionally produces pain and evident swelling, but more commonly is noted in the x-ray because it becomes the site of fracture which may be of the "spontaneous" type, i.e., occurs following normal movements or with very slight trauma. The x-ray shows an expanding central defect with



Fig. 28. Recurrent enchondroma of the sternum. The original tumor was removed six months previous to the recurrence shown in the photograph. Though histologically similar to the tumor illustrated in Figure 27 this type is quite different in its clinical behavior. The photomicrograph is from a section of the original tumor and shows typical chondroblasts.



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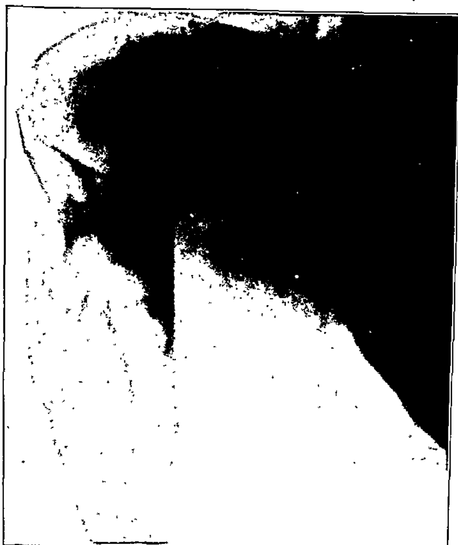


Fig. 29. Bone cyst. This is a solitary lesion as was shown by x-rays taken of many other bones. The lesion was noted because of the fracture which was sustained while the patient, a healthy 21-year-old male, was pitching a baseball. The fracture was treated just as if no cyst were present, and healed normally.

thinning of the cortex. The cavity contains clear or straw-colored fluid and is lined by cells showing fibrous tissue and some new bone formation. Phemister has presented evidence that the lesion is inflammatory in origin. Treatment in case of fracture is the same as if the cyst were not present; complete union and disappearance of the lesion is the rule. If operated on because of swelling or pain, the cavity is opened and swabbed with an antiseptic, such as alcohol, and the wound closed. Some surgeons fill the cavity with bone chips to promote osteogenesis. Lack of healing points to the existence of a systemic disturbance—such as Paget's disease of bone, generalized osteitis fibrosa, or bone lesions due to parathyroid tumor.

(*d*) *Benign Giant Cell Tumors.* This tumor occurs in many bones but is most common in the epiphysis of the lower femur, upper tibia, and distal radius. It produces pain, is often preceded by a history of trauma, and may be the site of fracture, thus resembling the symptoms produced by a bone cyst. X-ray reveals a central translucent trabeculated osteolytic lesion which has expanded and thinned out the cortex, perforating it often and invading soft tissue. *The fact that it involves the epiphysis is often of diagnostic value.* At operation, the tumor often appears hemorrhagic, bleeds when touched, and is soft and friable. Histologically, it contains many giant cells in contrast to malignant bone tumors which contain only a few such cells. Treat-

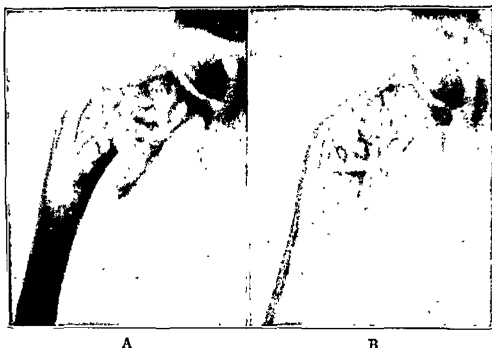


Fig. 30. Benign giant cell tumor. The existence of the lesion was discovered only by x-ray which was taken because the patient, aged four, had fallen and sustained a fracture. A, x-ray taken at time of injury; note the trabeculated nature of the shadow as well as the expansion of the cortex. B, x-ray taken three months later; the fracture was treated by reduction and immobilization in a plaster cast. This patient, now eight years old, is normal in every way.

ment includes radiotherapy, operation, or both.

Tumors containing giant cells comprise a variety of lesions (Fig. 30). Certain types of malignant bone tumors, though containing giant cells, have obviously an entirely different clinical significance. Giant cell tumors of the jaw, subperiosteal giant cell tumors, spindle cell variants, and types of giant cell variants in osteitis fibrosa present special features. Many giant cell tumors of bone are manifestations of hyperparathyroidism (see Ch. 39). The extraskeletal giant cell tumors include epulis, xanthoma, and giant cell tumor of the tendon sheath.

(*e*) *Multiple Cystic Disease.* This bone disease was described in 1891 by von Recklinghausen and is sometimes called Recklinghausen's disease; however, it has no connection with the more commonly known disease, neurofibromatosis, which he described in 1882 and which also goes by his name. The bone disease is often called osteitis fibrosa cystica or osteoplastica, but as originally described. Similar bone defects are observed in hyperparathyroidism as discussed in Chapter 38.

II. Nervous Tissue Origin. True neural tumors are rare except those in the brain (glioma), and as part of such other tumors as fibroneuroma (Fig. 31). Those which arise from the sympathetic nervous system are usually malignant and are called a variety of names, such as sympathicoblastoma and ganglioneuroma. *Carotid body tumors* belong to the chromaffin tissues which might be classed as of nervous origin. They are extremely rare and present themselves as a spontaneous, usually asymptomatic, swelling below and behind the angle of the jaw. Treatment is excision. (See also p. 652.) Spina bifida and meningocele are not really neoplasms and are described elsewhere. In the peripheral nerves, traumatic *neuroma* may result following injury or division of nerves. These are discussed in detail in Chapter 27. *Glomus tumors* are rare, tiny neoplasms which, however, contain vascular and epithelial as well as nerve tissue. They occur most frequently in the nail bed and about the



A



B

Fig. 31. Photomicrographs of a neurofibroma, stained to show nerve elements. A, nonmyelinated nerve fibers intermingling with collagen in a peripheral neurofibroma; B, myelinated nerve fibers entering a neurofibroma (Morgan myelin sheath stain). (From Penfield. Cystology and Cellular Pathology of the Nervous System, Paul B. Hoeber.)

fingers and toes, elbow, knee, and leg. The tumors are characteristically painful, either spontaneously or to the touch, and therefore demand excision.

An easily recognized type of *neurofibromatosis* is *Recklinghausen's disease,* a rare but disfiguring affliction due to extensive multiple tumors of the skin (Fig. 32) and rarely of the deeper tissues. The tumors originate from the neurilemmal sheath of peripheral nerves and contain definite nerve filaments which, while diagnostic of the disease, are demonstrable only with special stains. Even though named after the German physician who reported the disease in 1882, a Dublin surgeon, Robert W. Smith, first described the condition in 1849 in a monograph which was privately printed and apparently lost to medical records. Fulton, in 1929, called attention to this communication. The eponymic term applied to the disease should possibly be that of Smith, whose description was accurate and included microscopic observations and carefully executed plates illustrating the lesion.



Fig. 32. Multiple neurofibromatosis. The patient was a 45-year-old Negress. No symptoms were present, except for moderate disability due to a tumor in the right axilla which was excised for that reason.

Clinical manifestations are generally due only to the appearance of tumors themselves. Pain, though generally absent, may be present in some cases. Because the tumors are often white, soft, and pedunculated, the term *fibroma molluscum* is also used. Areas of skin

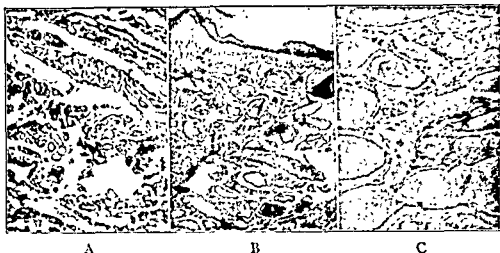


Fig. 33. The three types of blood vessel neoplasms described in the text. A, capillary hemangioma; photomicrograph is from a small port-wine stain excised from the neck of a two-month-old infant. Note the numerous small capillaries in the midst of many angioblasts; all of the channels contained blood. B, hypertrophic hemangioma; photomicrograph is from a small red tumor with roughened surface, removed from the arm of a six-year-old girl. Note the dilated thin-walled channels filled with blood. C, cavernous hemangioma; photomicrograph is from a tumor, about 3 cm. in diameter, over the elbow of a 12-year-old boy. A small tumor was present at birth but it began to grow markedly in the past three weeks. The skin may not be involved in this type of hemangioma. Note the thick-walled large sinuses filled with blood. This cavernous appearance is possessed by most of the hemangiomas encountered in the deeper structures of the body.

pigmentation are so frequently encountered as to be of diagnostic value. In addition to the skin lesions, which vary in size from that of a pea to that of a grapefruit, tumors are also found in the bone, central nervous system, and pelvis where they may cause severe symptoms of pain and disability merely by their pressure. Malignant (sarcomatous) changes are occasionally encountered and, unless the growth is removed early, recovery may be impossible. There is no treatment for the multiple skin tumors since they are usually too numerous for complete excision. When large and causing symptoms by pressure, removal may be urgently indicated. *Perineurial fibroblastoma* occurs in the same locations as Recklinghausen's disease but is usually single. Histologically it is differentiated from neurofibroma by the fact that the nerve fibers do not pass through the tumor nodule. They are common only along the eighth nerve (acoustic neuroma). Their treatment belongs to the domain of neurosurgery.

III. Blood Vessel Origin. Many of the various tumors arising from blood vessels are of neoplastic nature. Such lesions as aneurysms and arteriovenous fistulas are described in detail in Chapter 25. The blood vessel neoplasms are called angiomas or hemangiomas (Fig. 33) in contrast to lymphangiomas, which are somewhat similar in structure but contain lymph instead of blood. The angiomas are new growths, containing vascular tissue of capillary, venous, or arterial origin with a variable amount of connective tissue stroma. The vascular spaces are lined by endothelium and may be very large. Though congenital and present at birth, they sometimes have a power of growth which develops later or they may remain occult until adult life when symptoms may be produced. They occur in practically all tissues of the body and assume a great variety of clinical forms, to which many terms have been applied. Of those located in the deeper structures, most are of the cavernous type (see p. 413) and usually produce symptoms by pressure or by abnormal bleeding. They occur in the brain, orbit, intestines, pelvic organs, muscle, and especially in the liver and gastrointestinal mucosa, where they may be a rare cause of gastrointestinal hemorrhage. Symptoms depend on their location and size. True malignant change, including metastasis, has been described in angiomatous tumors, but it is extremely rare.

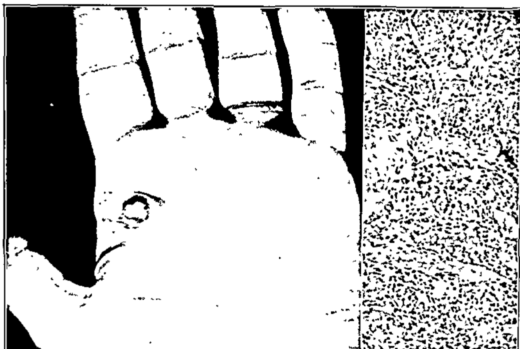


Fig. 34. Infected hemangioma of the hand. The patient was a 22-year-old housewife. This is a not uncommon type but the true diagnosis is often masked by the secondary inflammation which gives to the lesion the appearance of exuberant granulation tissue. This tumor was in the form of a papilloma and was easily excised. The photomicrograph reveals the true nature of the tumor; the dilated blood spaces resemble those shown in Figure 33B.

The visible hemangiomas, i.e., those which occur in or under the skin and mucous membranes, are perhaps the most common. In spite of the large and confusing terminology often applied to these lesions, the following classification has been adopted.

1. Capillary Hemangioma. The capillary hemangioma, or flat vascular nevus, is well known as the *port wine stain* and is sometimes called nevus flammeus or vinosus. Though a neoplasm, it is manifested not as a tumor at all, but as a disfiguring red or purple discoloration due to a plexus of newly formed, but normally sized capillaries in the corium of the skin. Its origin is probably due to some accident of maldevelopment during embryonic life, though popular superstition ascribes its etiology to some profound nervous shock to the mother while pregnant. Port wine stains ordinarily maintain a constant size and rarely increase in extent. The problem of treatment is a real one in the large areas which occur on the face or head. The use of radium has caused satisfactory blanching in some cases although it may be followed by a disfiguring scar. Skilled dermatologists sometimes achieve excellent results with carbon dioxide snow. Various tattooing devices have also been used. Excision and skin graft may occasionally be indicated.

2. Hypertrophic Hemangioma. The hypertrophic hemangioma, also called *angioma simplex* or angioma plexiforme, differs from the capillary nevus in being a true tumor, raised above the surface of the skin, though composed similarly of newly formed capillaries which, however, are dilated. The tumor varies in size from a millimeter to several centimeters in size; it shades gradually into the larger ones which are generally called cavernous angioma and have different histologic characteristics (see below). In color, the hypertrophic hemangioma varies from a bright red to a dull purple. The large, red tumor is often called a strawberry mark. Over 75 per cent of these tumors are on the head, commonly over the forehead, occiput, scalp, or lip, but may occur over any part of the body. The clinical course of this small angioma varies. A few seem to shrink and disappear. In some instances they ulcerate (Fig. 34), become infected, slough, and heal, leaving only a tiny scar. Most of them remain stationary or merely grow with the growth of

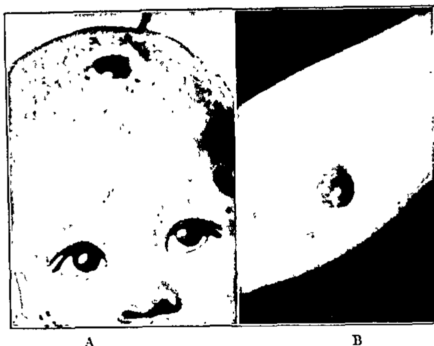


Fig. 35. Hypertrophic hemangiomas. A, the patient is a three-months-old infant; the tumor has been growing slowly since birth. Obliteration of the tumor was achieved by the use of radium. B, the patient is a five-year-old girl and the tumor of the leg has been growing slowly for several months. This tumor was excised. Section revealed a microscopic appearance approximately midway between that shown in B and C of Figure 33.

the child and are presented for treatment in childhood (Fig. 35) or adult life because they act as a cosmetic blemish. Of great importance, however, is the tendency of some of those tumors to exhibit rapid active growth, particularly in infants. If this occurs, a tiny birthmark of apparently no significance may finally involve an entire eyelid, nose, or lip, or spread over half the face or scalp, and finally become a true cavernous angioma. It must be emphasized, therefore, that every angioma in infants, regardless of its size, should be watched carefully and be removed even in the first weeks of life if any growth occurs. The treatment of the small lesions is relatively simple. Electrotherapy, irradiation of various types, and other means have been used, but should be carried out only by those expert in their use. Surgical excision is sometimes possible when the lesion is superficial.

3. Cavernous Hemangioma. This disfiguring vascular tumor usually involves a large part of the scalp, face, tongue, or other part of the superficial surfaces. Like the other vascular neoplasms, the tumor disappears on pressure but fills up rapidly. It differs from the other two types because of its size and because it contains true vascular channels (venous and arterial), which resemble the structure of the corpora cavernosa of the penis, hence its name. Cavernous hemangiomas present a grave problem in treatment, especially when they involve the face, for they are not only extensive superficially but often penetrate deeply and bleed profusely if any part of the mass is incised, thus making hemostasis during excision difficult. Because of the difficulties of surgical excision, other methods of treatment—such as diathermy, radiotherapy, and injection of various substances—have been tried from time to time and, in some instances, gratifying results have been achieved. The choice of method depends on the size and location of the tumor.

Other forms of congenital vascular tumors of the skin are described but are rather rare. *Angioma racemosum* or cirsoid aneurysm is composed of both arteries and veins which form large, serpentine swellings that pulsate visibly and give rise to an audible bruit due to the presence of many communications between the venous and arterial channels. They

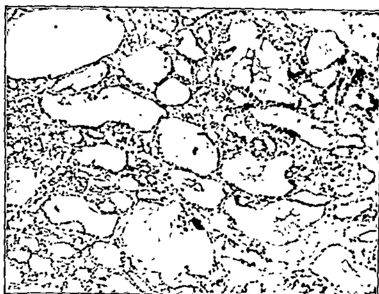


Fig. 36. Lymphangioma of the tongue. Photomicrograph of a tumor removed from the tongue (25-year-old woman. Note the dilated, thin-walled channels, which are, however, filled with lymph not red blood cells. Another differential feature is the frequent presence of nests of lymphocytes wl are seen only in lymphangiomas and not in hemangiomas. However, this tumor did not possess this ferentiating feature.

are in reality not neoplasms, but congenital abnormalities of blood vessels (arteriovenous fistula) and are described in some detail on page 569.

IV. Lymphatic Origin. Lymph channels are frequently involved by obstructive and inflammatory, but only rarely by neoplastic, disease.

1. LYMPHANGIOMA. This neoplasm of the lymphatic channels occurs in a great many clinical forms, usually, however, as a boggy tumor of the skin and subcutaneous tissue more particularly where the lymphatics are abundant (Fig. 36). It may occur in the form of a pedunculated mass. Lymphangioma may be a diffuse, slowly growing tumor involving the tongue or lip, giving rise to *macroglossia* or *macrolabia* (*microcheilia*), respectively. The tumor may be so disfiguring or result in such disability as to require excision and plastic repair. It should not be confused with *hemihypertrophy*, a rare congenital abnormality involving half the tongue, the lips, or even the entire head. Microscopic study reveals the difference. Lymphangioma often occurs concomitantly with cavernous hemangioma, which is occasionally associated with a type of varicose veins. Lymphangioma frequently contains islands of lymph cells in addition to lymphatic vessels. The channels themselves vary in size and, when large, p sent a cystic appearance (hygroma or ly phangiocysticum). When it occurs in neck (usually in infants), it is called *cy hygroma* and consists of multilocular lym filled sacs arising in the tissue beneath deep fascia. The large cystic mass (Fig. 3 frequently produces serious obstruction the trachea and esophagus and occasiona becomes infected, necessitating drainage. E cision is often difficult or impossible. Inj tions of sclerosing solutions are often usef Lymph nodes themselves do not give rise benign tumors of neoplastic origin except a part of lymphangioma. When enlargeme of lymph nodes occurs it is due either to i flammatory causes or to malignant diseas

2. THYMOMA. The term "thymoma" loosely applied to tumors originating from tl thymus gland. Actually there are vario types of growths, mostly malignant, whi cause symptoms by increased mediastin pressure. Thymic enlargement is physiolog in infants; when excessive, it is known *status thymolymphaticus*, a condition whic is also associated with general lympho hyperplasia and is supposed to be a cause sudden death in children.

V. Muscle Tissue Origin. Myoma of th uterus, often called fibromyoma because



Fig. 37. Cystic hygroma. In this child, aged 10 months, the lesion had grown since birth. Wide dissection is necessary for a cure.

contains fibrous as well as smooth muscle tissue, is common. It often grows to huge size and produces many local symptoms and signs (see Ch. 40). Leiomyoma, occasionally found in the stomach or intestine, is a cause of gastrointestinal hemorrhage. Though benign tumors of striated muscle (rhabdomyoma) also occur, they are so rare that they are recognized only after microscopic examination.

VI. Mixed Tissue Origin. There are two types of tumors in this classification: mixed tumors and teratomas.

1. MIXED TUMORS. This type occurs most frequently in and upon the salivary glands, most commonly the parotid (Fig. 38). Mi-



Fig. 38. Unusually large mixed tumor of the parotid. The patient was 47 years old. The tumor was first noted 18 years previously; after excision it recurred and grew more rapidly for four years when it was excised a second time. The present tumor is the second recurrence which has been growing slowly for 14 years. An extensive dissection was necessary before the tumor could be completely removed. The photomicrograph shows cords of epithelial cells which seem to form intercellular myxomatous material.

croscopic section reveals not only mesodermal cells, such as cartilage and fibrous tissue, but also epithelial elements and other tissue unrecognizable as to origin. There is usually a history of a small quiescent tumor for several years preceding active growth. When growth is rapid it is frequently indicative of malignant change. The typical tumor is firm, limited, and presents a nodular surface, later becoming cystic. These tumors recur unless completely and carefully removed together with their surrounding capsule. If not completely excised, an appreciable percentage of these tumors ultimately become malignant. Benign teratomas are also composed of mixed tissue, but are more obviously embryonic rests, and are described below.

2. TERATOMA. The teratoma represents, according to most authorities, an absorbed or partly grown twin which stopped development at some early stage and became encapsulated by the other normal fetus. Thus it contains, as already mentioned, mixed or diverse structures which are epithelial and mesodermal, e.g., muscle, hair, teeth, intestine, and the like. Great variations in size and development occur. A teratoma usually develops in the mid-line but is found most frequently in the testicle, ovary, sacrococcygeal region, and mediastinum. It causes symptoms by pressure, by undergoing malignant degeneration, or by both. It is, of course, present at birth, but often remains occult until symptoms develop later in life. It is described in detail in later chapters. When a teratoma contains skin elements only (hair and sebaceous material), it is often called a dermoid.

VII. Epithelial Cell Origin. The various benign tumors of epithelial origin are a rather heterogeneous group and, although a few are common, they represent in general rather rare types of benign tumors. They comprise three arbitrary groups: adenomas, skin tumors, and tumors of the jaw.

1. ADENOMA. This tumor is a benign collection of epithelial cells originating from glandular tissue. In endocrine glands, the tumor may actually function as secretory tissue, as noted in the hypoglycemia produced by adenoma of the islets of Langerhans of the pancreas (see Ch. 39). In the thyroid, adenomas may also cause symptoms but frequently occur "silently" without producing any manifestations of functional activity. In the pituitary, an adenoma may lead to abnormalities in growth; in the adrenal, it may produce peculiar sex development. Adenoma of the parathyroid may result in abnormal calcium metabolism and the formation of multiple bone lesions and renal calculi. When adenomas form in glands with external secretions, they rarely cause symptoms from functional activity since they rarely function as normal tissue. Thus an adenoma of the breast (usually fibroadenoma or intracanalicular fibromyxoma dependent on its microscopic features) does not produce milk but merely manifests itself as a circumscribed lump which is sometimes painful. Other circumscribed adenomas include the sebaceous adenoma which, though rare, may be the site of squamous or basal cell epithelioma. Treatment of adenoma consists of excision. *Rhinophyma* is a peculiar enlargement of the nose due to hypertrophy rather than to actual neoplasm of the sebaceous glands and skin. Plastic repair is often indicated.

Attention should be called to adenomatous hyperplasia which may result in papillomatous formation, especially in the stomach and colon (polyposis). Other examples of adenomatous hyperplasia are fungous or glandular endometriosis in the uterus, and prostatic hypertrophy.

2. EPITHELIAL BENIGN TUMORS OF THE SKIN. Prominent among the benign skin tumors are warts, cutaneous horn, and moles (or benign melanoma).

(*a*) *Warts* (*Verruca Vulgaris*). Warts are epithelial neoplasms originating from the germinative epithelium of the skin (Fig. 39). They sometimes are papillomatous, but usually are manifested as a cone-shaped elevation with a flat top whose surface exhibits a characteristic cauliflowerlike appearance and numerous tiny black dots. Warts have a tendency to become irritated, painful, and occasionally infected. Ordinarily, however, they produce no symptoms or, at the most, a slight "sticking" sensation. Nevertheless, when the warts are located under the nail, on the cuticle, or on the sole of the foot, pain may be pronounced. The tumor occasionally disappears spontaneously, sometimes within a short time after its development. This feature undoubtedly accounts for the reputed

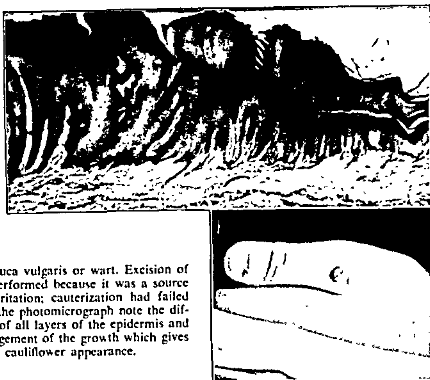


Fig. 39. Verruca vulgaris or wart. Excision of the tumor was performed because it was a source of mechanical irritation; cauterization had failed to destroy it. In the photomicrograph note the diffuse hyperplasia of all layers of the epidermis and the peglike arrangement of the growth which gives to the surface its cauliflower appearance.

efficacy of the many home remedies, some mixed with the use of magic formulas which have been used from time immemorial for their removal. The wart has considerable theoretical interest because, although possessing all the characteristics of a true neoplasm, evidence indicates that it is in reality an infection due to a filtrable virus. Thus, if the tumor is excised aseptically, ground up, and passed through a Berkefeld filter, the clear filtrate upon injection into the skin will give rise to a new wart. This probably explains why warts may appear and disappear suddenly without apparent reason, and why they may spread by contact as from one finger to a comparable point on the next digit or directly from a distal point to one proximal to it. It has been said that if we knew the pathogenesis of the common wart we would know something about the etiology of cancer.

Treatment is rarely indicated for cosmetic reasons because warts ordinarily grow on the hands and feet (Fig. 40). When infection is present it should be treated first. The tumor may be either destroyed or excised. Destruction of the wart may be achieved with 1. the x-ray; 2. by some form of cautery, e.g., electrical, thermal, or by chemicals (fuming nitric acid, trichloracetic acid, salicylic acid); or 3. surgical excision. Palmar and plantar warts are often the most difficult to eradicate. Irradiation is often effective in treating plantar warts but must be used with great care and only for one trial; if the lesion does not respond, surgical excision should be used. When the wart is more superficial and in soft, thin skin, chemical cauterization is the simplest method and consists simply of applying a drop of the acid over the plateau of the wart (not involving the adjacent skin) and letting it seep in. When it has reached the base of the growth a burning sensation is noted by the patient. The excess acid is then wiped off. The process may be repeated in 48 hours. After several days the wart drops out, leaving a shallow insignificant ulcer which heals readily. If a tiny recurrence occurs it can be treated similarly later.

(*b*) *Cutaneous Horn* (*Cornu Cutaneum*). The cutaneous horn is a form of cutaneous wart in which the horny layer (cornified epithelium) gives rise to the actual tumor. It may consist of a small area of hyperkeratosis, but fair-sized hard projecting growths may form, chiefly on the scalp.

(*c*) *Moles or Pigmented Nevi.* Moles occur commonly in the skin and are usually congenital. A much better term is *benign mela-*



Fig. 40. Plantar wart. The patient was a 16-year-old girl. Symptoms of pain and disability were marked. Note the slight redness, indicative of a mild degree of inflammation. Radiotherapy was curative in this case; it is obviously a very convenient form of therapy. Unfortunately it is not always effective.

noma. Clinically, benign melanomas are small raised areas which occasionally take the form of a papilloma and often have hairs growing out of them. Their importance lies largely in the fact that certain types give rise occasionally to the highly malignant melanoma (see p. 389). Excision is generally advisable if moles become chronically irritated or bleed, if sudden enlargement occurs, or if they are present on the feet. They may also be destroyed by the electrical cautery. Occasionally they are removed for cosmetic reasons when present in an exposed part of the body, particularly in young women.

3. JAW TUMORS. Though largely of ectodermal origin, jaw tumors comprise a great variety of neoplasms. They are varieties of odontomas or tumors derived from special cells concerned with the development of teeth. The following groups are described, modified from their classification:

(*a*) *Adamantinoma.* This neoplasm is a solid or often multilocular cystic tumor which develops within the alveolar bodies of the maxilla, but more frequently in the mandible. Microscopically it contains cells of squamous epithelium, or fibrous tissue, and even of the enamel organ. Clinically, it is slowly growing, is present most commonly in the molar region, and produces no pain. When large, it may present a lobulated surface and, upon pressure, the thin walls of the cyst may produce a sensation as of the crackling of parchment or celluloid. Excision is the only form of treatment, but must be complete in order to avoid recurrence.

(*b*) *Dentigerous Cyst* (*Odontocele, Corodental Cyst, Periosteal Cyst*). The dentigerous cyst is probably the most common tumor of the jaw and is a benign hollow cyst lined with epithelium containing viscid straw-colored fluid with a partly or fully developed tooth projecting into the cavity (Fig. 41). Symptoms arise only when they reach a sufficient size to be noticed. When large, the cyst may give a sensation of "celluloid crackling." Treatment consists of complete removal of the cyst and its capsule and extraction of the tooth. A *dental root cyst* is another type of jaw tumor and results from irritation of the dental epithelial cell rests in the peridental membrane of a tooth that has undergone eruption, usually a pulpless tooth.

(*c*) *Composite odontoma.* This is a calcified tooth tumor composed of varying elements which often demands excision.



Fig. 41. Dentigerous cyst. The patient was a 25-year-old male. This lesion produced no symptoms and was first noted in the roentgenogram which was taken because of an injury to the jaw. Note the fracture line extending into the cyst. (St. Louis City Hospital.)

(*d*) *Osseous tumors.* These tumors also occur in the jaw. In addition to the various types of benign bone tumors which may develop in the jaw, the so-called *fibrous osteoma* is a characteristic growth of the mandible.

All jaw tumors may become infected and the true nature of the tumor may thus be obscured. The roentgenogram is usually characteristic and enables an accurate diagnosis in most cases.

C. CYSTS

Cysts form a special group of tumors which owe their swelling to the presence of fluid rather than to cellular elements. However, the designation is far from absolute for many solid tumors contain cystic areas and many cysts harbor solid cellular areas. The clinical designation may also be difficult in that some sarcomas are soft and fluctuant as if they contained fluid, whereas some cysts contain fluid under such high tension that on palpation they resemble a hard, solid mass. Such difficulties, however, may usually be overcome by aspiration of the tumor. Cysts are much more difficult to classify than other tumors. The following groups, therefore, represent a purely arbitrary classification.

1. Retention Cysts. These tumors form because the duct of a gland becomes occluded, usually by inflammation, so that the secretion of the gland accumulates as a cyst.

Galactocele is a type of retention cyst in the breast which occurs during lactation and will be discussed in Chapter 35. *Mucoceles* are tiny cysts, commonly in the mouth, which are due to the occlusion of the opening of a tiny mucous gland. *Ranula* is a retention cyst located in the floor of the mouth under the tongue, is first confined to one side, later projects across the mid-line (Fig. 42). It is caused by an obstruction of one of the tiny, sublingual ducts which becomes distended with clear, mucoid material and often attains a large size.

The most common representative of the retention cyst is the so-called *wen* or *sebaceous cyst.* In its simplest form it manifests itself as the ordinary comedo in which the retained sebaceous material is visible under the skin. In its most pronounced form it presents a semispherical elevation in the skin to which it is attached. The tiny opening of the obstructed gland can often be seen at the apex of the tumor. It occurs most commonly in the scalp, back, and neck and may be multiple (Fig. 43). It is soft and fluctuant, containing characteristic greasy, thick, grayish paste. The contents sometimes escapes spontaneously or on pressure through a tiny opening, only to refill again. Complete excision of the sac is curative. Sometimes the cyst becomes infected, whereupon it presents the signs of an abscess which should be incised. The infection may destroy the secreting cells so that after inflammation subsides, recurrence may not occur. If it does fill up, excision can then be done. Malignant degeneration (carcinoma of a sebaceous gland) is rare but should be

Fig. 42. Ranula. The patient was a four-year-old boy. The smooth cystic tumor was *noted by the* mother accidentally. It increased in size steadily. Note that it is confined to one side of the floor of the mouth and does not cross the mid-line. Treatment consisted of complete excision of the cyst.



Fig. 43. Sebaceous cysts. Two of these tumors are present in this patient; they are of many years' duration and have been increasing *slowly in size. The one at the back of the head,* though unusually large, is in a characteristic location above the hairline; it was excised under local anesthesia and contained typical grayish greasy sebaceous material.

suspected if a draining sinus persists and fails to heal after incision of any superficial abscess of the skin or if a cyst develops sudden growth or unusual vascularity.

II. Degeneration Cysts. This term applies to cysts that sometimes form at the site of large hematomas which, instead of becoming absorbed and replaced with fibrous tissue, liquefy and remain as permanent tumors. They may be present in the abdomen after an intraperitoneal hemorrhage, in the chest, or in the brain. Ordinarily, the fluid is first brownish but later it undergoes changes which convert it into hematoidin (same as bilirubin), and colors the fluid yellow. Occasionally cholesterol crystals are found in such degeneration cysts.

III. Neoplastic Cysts. Neoplastic cysts generally include those which depend for their formation on a new growth, although in most cases the new cells are in reality abnormalities, congenital in origin. Ovarian cysts of various types have been described and belong in this group. Bone cysts have been described elsewhere under bone tumors.

IV. Dermoids or Dermoid Cysts. These terms should, in reality, include only cysts dependent for their formation on an inclusion of squamous epithelium under the skin. In some instances the cells continue to function as normal skin, and a cyst containing hair, sebaceous material, and cellular débris is formed. The small cysts, however, contain only clear fluid. The inclusion is usually congenital and occurs around the orbits, temple, mastoid and neck, or floor of the mouth. When a similar cyst is encountered in the ovary or mediastinum it should, in reality, be classified as a teratoma containing only epithelial elements. Dermoids of the skin, moreover, unlike ovarian and mediastinal dermoids, practically never undergo malignant change. Excision of the dermoids of the skin is indicated chiefly for cosmetic reasons. Those in the floor of the mouth are in the mid-line and may cause pressure symptoms; they are very rare, but should not be confused with ranula, which is unilateral. Those over the forehead should be distinguished from meningoceles which communicate with the brain; they may also be confused with lipomas and sebaceous cysts. Dermoids which occur in the sacral region are called pilonidal cysts or sinuses, and are seen frequently.

A *pilonidal cyst* is a derivative of skin ectoderm which becomes invaginated during embryonic life and remains only as a vestigial skin appendage, which develops at puberty (Fig. 44), thereby explaining its age distribution. Thus it rarely produces clinical manifestations until young adult life (20 to 25 years), and then only because the cyst becomes infected and forms an abscess which usually opens spontaneously and gives rise to a chronic draining sinus. This sinus may close, fill up, break down, and discharge intermittently. Occasionally the infection undermines the subcutaneous tissue over the coccyx and results in an extensive abscess. Even if drainage is adequate, healing will not occur, presumably because of the presence of living and therefore secreting epithelium in the lining of the tortuous sinus. During World War II, it assumed great importance because of its frequency and because it caused prolonged disability among the enlisted personnel. Many soldiers felt that riding on the hard seats of jeeps was a causative factor, which explains its popular name, "jeep disease."

Inspection in the sacral region will nearly always reveal one or more tiny dimples in the mid-line over the coccyx. They resemble in appearance the preauricular dimple seen in a branchial cyst at the first cleft (see p. 423). Such dimples are common and, on rare occasions, may be associated with severe local pain in absence of infection. Ordinarily, however, the superimposed infection contributes nearly all the local signs and symptoms. The location of the abscess or sinus opening over the coccyx plus the mid-line dimples are sufficiently characteristic to easily differentiate pilonidal infections from ischiorectal abscess and fistula in ano.

Treatment consists of complete excision of the diseased tissue after allowing acute infection to subside. All cells lining the tract must be removed, else recurrence is inevitable. This requires, in most cases, a rather extensive dissection; preliminary injection of the tract with methylene blue will aid in complete excision. Unless severe infection is present, the tract should be excised and the wound closed without drainage. However, in order to avoid a high incidence of infection and recurrence,

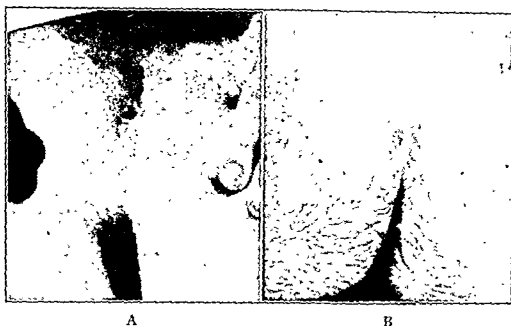


Fig. 44. Two examples of pilonidal sinus. A, in a 20-year-old girl; symptoms started at puberty with the appearance of a tender coccygeal mass which opened and drained pus only to heal and recur at intervals of many months. The photograph was taken a few days after the last abscess had opened and drained. Excision of the entire track was performed later after the acute inflammation had subsided. B, a more characteristic appearance in a 25-year-old male with a similar history. The acute infection has long since subsided and now exhibits only a tiny, chronically draining opening; the tract itself, however, extends upward and medially for several centimeters.

excellent surgical technic, including use of a minimal number of fine sutures, and elimination of all dead space must be exercised. When severe infection is present, the wound, after excision of the fistula, is packed open and allowed to close by granulation and fibroplasia.

Epidermoid cysts are similar in pathogenesis to dermoids except that they are due to traumatic inclusion of epithelial cells, often after a trivial wound, in which the cyst later develops. They are smaller than dermoid cysts, contain only clear fluid, and are common in the hands (fingers) and feet. Treatment consists of simple excision.

V. Congenital Cysts. This group includes several types:

1. Branchial Cleft Cysts. These cysts originate from the embryonic branchial clefts and hence occur in the lateral aspect of the head or neck along a line extending from the ear to the midclavicle (Fig. 45). The most common location is at the site of the first branchial cleft; a preauricular dimple is frequently seen and is often associated with a cyst just below and anterior to it. The cysts of the upper clefts are usually small, but those lower in the neck may attain considerable size. If they open or are incised they become the site of a chronic draining sinus. The cells lining the cyst in most instances are squamous in type, and the wall also shows many collections of lymphoid cells. Because of their similarity in structure, branchial cleft cysts are often classified with dermoids. Branchial cleft cysts which are deeper may communicate with the oral and pharyngeal cavity and exhibit columnar rather than squamous epithelium. Occasionally carcinomatous changes develop in them (Fig. 46). Their treatment consists of complete excision.

2. Thyroglossal Duct Cyst. This cyst is always in the mid-line of the neck and is a remnant of the thyroglossal duct which, in embryonic life, extends from the base of the tongue (foramen cecum) beneath the hyoid bone to form the thyroid gland (Fig. 47). Any portion of this tract may be left and give rise to a cyst in later life. It often opens spontaneously, after which it may manifest itself as a chronic draining sinus or as a cyst which opens, drains, closes, and fills up intermittently. Treatment consists of complete excision which may be difficult and may neces-



Fig. 45. Branchial cleft cysts at two different clefts. A, cyst of the first branchial cleft; note the preauricular dimple which is associated with the cyst but is often present alone; B, cyst of a lower cleft. Excision was performed in both cases; the lining of the cyst consisted of squamous epithelium and also contained nests of lymphoid cells.



Fig. 46. Carcinomatous change in branchial cleft cyst. The patient was a 70-year-old man. The tumor was of steady growth, apparently of only six months' duration. Aspiration of a cystic area yielded sufficient tissue to make a diagnosis of cancer. Complete excision was performed under local anesthesia.

sitate a dissection up to the base of the tongue. If any epithelial cells remain, recurrence follows. It is an operation which should not be undertaken lightly.

3. MENINGOCELE AND SPINA BIFIDA. These cysts are forms of congenital cysts due to failure in development of the central nervous system and its meninges and bony cover-



Fig. 47. Two examples of thyroglossal duct cysts. A, the cyst has not been opened. Note its position in the mid-line. It has been present for many years with very little increase in size; B, in this patient the cyst had been incised some years previously and the depressed scar is the site of a chronic draining sinus. The entire tract was excised; as is usually the case, an extensive dissection almost to the base of the tongue was necessary.

ing (Fig. 48). Spina bifida is most common over the lumbar region as a cystic mass and may be associated with motor and sensory disturbances. X-ray will reveal a bony defect, nearly always a bifid spine. Meningocele is really a herniation of the spinal or cerebral meninges through any bony defect which, however, is generally insignificant in size. It

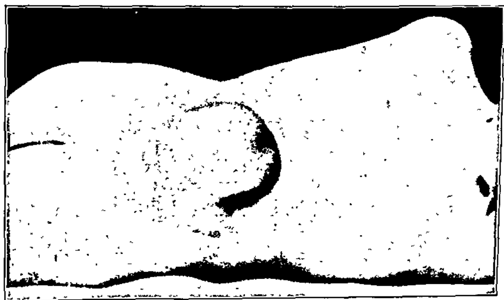


Fig. 48. Spina bifida and meningocele. The patient was a three-year-old girl. The mass was first noted at birth; the child had no use of either leg but was not incontinent. The defect in the spine could be felt clearly; transillumination showed a clear sac. Operative excision of the sac and plastic repair were performed; recovery was uneventful. Four years later the reflexes were still absent but the child was going to school, her grades being above normal. (Courtesy Dr. Ernest Sachs.)

is seen commonly in the lumbar region and less frequently in the mid-line over the forehead or occiput. *Treatment belongs to the* domain of neurosurgery.

4. POLYCYSTIC DISEASE. This rare form of congenital cyst, usually manifesting itself in adult life, occurs in the lungs, kidneys, liver, and spleen.

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21

CANCER: RECENT CONCEPTS IN INCIDENCE, ETIOLOGY, DIAGNOSIS, DISSEMINATION, AND TREATMENT

INCIDENCE

Cancer ranks second, next to heart disease, as a cause of death in the United States. There are about 450,000 new cases per year and about 250,000 deaths, which represent about one sixth of the deaths annually. Contrary to popular belief, malignant disease is comparatively common in children. In 1956, 4,000 children under 15 years of age died of cancer, representing more deaths than from any other disease; only trauma accounts for more deaths in children. About half the deaths from malignant disease in children were caused by leukemia.

The number of deaths per year from cancer is increasing, not because treatment is less effective, or the incidence higher, but because cancer is a disease primarily of late adult life and people are living longer. In 1900, the life span was 48 years; whereas in 1957, it was an estimated 69 years. In spite of the increased incidence of cancer, the annual number of deaths for cancer in most sites of the body is leveling off because of improvements in therapy. However, the death rate from carcinoma of the lung is increasing sharply; for example in 1956, approximately 29,000 people died from carcinoma of the lung, which is fully six times the number 20 years ago.

The most common cancer in women is carcinoma of the breast; in men, carcinoma of the skin (1). The number of cases of and deaths from cancer in males and females have been assembled from vital statistics by Cameron (2) (Tables 1, 2).

ETIOLOGY

We must admit that the primary cause of cancer is unknown, although numerous secondary causes are known. These secondary agents might be classified as physical, chemical, or biological (3). Chronic irritation and inflammation represent secondary causes, but of more importance are the innumerable carcinogens which are known to be capable of producing cancer in animals. In surveying several hundred compounds, Hartwell (4) reports 320 as having carcinogenic qualities. There can be no doubt that this list is far from complete. We have only meager knowledge regarding the role of these agents in the production of cancer in the human being, although the hormonal influence (as will be discussed later) has been proved rather conclusively. It is very possible that certain of these factors, which we now classify as secondary, are actually primary factors. Only time and an enormous amount of research will give us the answer to this possibility. Certainly, some of the old theories, including Cohnheim's embryonal theory and the bacterial cause can perhaps be eliminated as having very slight or no etiologic importance.

TABLE 1. Estimated Cancer Incidence (1955) and Cancer Mortality (1953) in the United States Among Men

(After Cameron, in M. Clin. North America, May, 1956)

Site	Number	Total Per Cent of Cases in Men	Number of Deaths	Per Cent of Cancer Deaths in Men
Skin	31,000	13.6	2,095	1.8
Lung and bronchus	26,000	11.4	19,740	16 6
Stomach	24,000	10.5	14,752	12.4
Prostate	24,000	10.5	12,595	10.6
Large intestines	20,000	8.8	10,885	9.1
Buccal cavity and pharynx	15,500	6.8	3,995	3.4
Urinary organs	15,500	6.8	7,210	6.1
Rectum	13,500	5.9	6,087	5.1
Lymphomas	8,000	3.5	2,606	2.2
Leukemia and aleukemia	6,000	2.6	5,740	4.8
Pancreas	6,000	2.6	6,008	5.1
Esophagus	6,000	2.6	3,253	2.7
Larynx	6,000	2.6	1,800	1.5
Liver and biliary passages	5,000	2.6	4,377	3.7
Brain and nervous system	4,000	1.8	2,990	2.5
All other sites	17,500	7.7	14,694	12.4
Total	226,000	100%	118,827	100%

TABLE 2. Estimated Cancer Incidence (1955) and Cancer Mortality (1953) in the United States Among Women

(After Cameron, in M. Clin. North America, May, 1956)

Site	Number	Total Per Cent of Cases in Women	Number of Deaths	Per Cent of Cancer Deaths in Women
Breast	52,000	21.8	20,342	18.5
Cervix uteri	25,000	10.5	13,500	12.2
Skin	24,000	10.1	1,485	1.3
Large intestine	22,000	9.2	13,130	11.9
Stomach	12,500	5.3	8,621	7.8
Rectum	12,500	5.3	4,607	4.2
Ovary	11,500	4.8	6,483	5.8
Corpus uteri	8,000	3 4	2,000	1.8
Urinary organs	7,000	2 9	3,705	3.4
Lymphomas	6,000	2.5	1,762	1.6
Liver and biliary passages	6,000	2.5	5,470	5.0
Lung and bronchus	5,000	2.1	3,762	3.4
Leukemia and aleukemia	5,000	2.1	4,178	3.8
Pancreas	4,000	1.7	4,157	3.7
Buccal cavity and pharynx	4,000	1 7	1,084	0.9
Brain and nervous system	3,000	1.3	2,093	1.9
All other sites	30,500	12.9	13,873	12.6
Total	238,000	100%	110,252	100%

however, there is strong evidence (as discussed later) that a virus may be a factor, even of the primary type.

Some of the carcinogenic agents are foreign to the animal or human being (extrinsic); others are produced either by the animal itself or by other living organisms of different species (intrinsic). Accordingly, these agents will be discussed under these two headings.

There is another group of compounds

called cocarcinogens, which alone cannot initiate cancer but can promote cancer after a true carcinogen has been applied. These compounds are recognized in the pathogenesis of cancer in animals, but there is no proof that they exert a role in the production of human cancer. Creosote and croton oil are examples of cocarcinogens. For example, a single application of 3,4-benzpyrene to the skin of a mouse may not induce cancer; but if its application is followed by repeated treatment with croton oil, tumors will develop (Mottram, 1944). Croton oil itself will not produce cancer, and if applied prior to the application of the benzpyrene it has no effect.

Extrinsic Factors. Perhaps the first evidence we have of the recognition of a carcinogenic agent was the description of cancer of the scrotum in chimney sweeps by Sir Percival Pott in the eighteenth century. After development of the coal tar industry during the next century it was noted that workers in the tar distillation plants were prone to develop skin cancer. This occupational relationship was so obvious that many scientists were induced to apply tar to the skin of animals with the hope of producing a cancer. Most of their attempts failed because the local applications were not carried out long enough. The first production of cancer by local application of tar was reported by Yamagiwa and Ichikawa (5), who painted the ears of rabbits for 15 months.

POLYCYCLIC HYDROCARBONS. The production of cancer by application of tar soon led to the fractionation of coal tar into its different components, many of which are carcinogenic. This fractionation (from tar) or synthesis of such compounds as 1,2,5,6-dibenzanthracene, 3,4-benzpyrene, and methylcholanthrene (Fig. 1), furnished a new weapon in cancer research. The synthesis of the latter compound from desoxycholic acid and cholic acid, which are important components of the bile, suggests that elements in the bile might be carcinogenic particularly since desoxycholic acid has been shown to be carcinogenic (6). The polycyclic hydrocarbons produce tumors at the site of application, unlike most of the other carcinogens which produce tumors at distant sites.

HALOGENATED ALIPHATIC HYDROCARBONS. These agents are not nearly as important in carcinogenesis as the polycyclic hydrocarbons. However, it is known (Edwards) that feeding carbon tetrachloride in olive oil to mice for several months will produce neoplasms of the liver (hepatomas) in a high percentage of animals. However, feeding this compound in rats produces hepatic cirrhosis, but no tumors.

AZO DYES. Work on these agents was stimulated by the discovery (Fischer, 1906) that scarlet red would induce epithelial proliferation (which was not a true tumor). When amino-azotoluene is injected subcutaneously to rats and mice, a tumor of the liver is induced after months (Yoshida, 1934). This experiment was particularly important because it was perhaps the earliest one to demonstrate the production of tumors distant from the site of injection. When 4-dimethylamino-azobenzene is fed to rats for several months, a hepatoma is produced (Kinosita, 1937), but only in animals fed on a deficient diet (Rhoads and associates, 7). Many other azo dyes, including several derivatives of amino-azotoluene are carcinogenic.

AMINO COMPOUNDS. In this group are included such compounds as aminofluorene (with numerous derivatives), aminodiphenyl, aminostilbene, naphthylamine (alpha and beta), urethane, and the nitrogen mustards. The azo dyes are really amino compounds, but have been considered separately

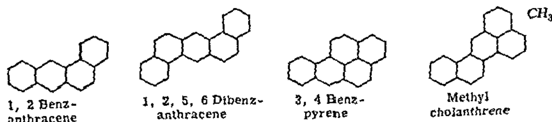


Fig. 1. Examples of extrinsic carcinogens (polycyclic hydrocarbons).

because they act so exclusively in the liver. The insecticide, 2-acetylaminofluorene, when incorporated in the diet of rats, will produce tumors in multiple areas (e.g., liver, bladder, breast) in three to four months (8).

FOODS. The possibility of certain foods being carcinogenic has been brought up by numerous workers, but no specific ones have been identified. The food itself could contain a carcinogenic agent or the harmful agent might be produced by the digestive process. It is conceivable that these agents might be carcinogenic to some people and not to others; this presumes that some people are blessed with the possession of anticarcinogens, which is discussed later.

TRAUMA. At times, there appears to be a relationship between trauma and the development of malignant tumors, but with very few exceptions this relationship is not valid; on most occasions it was some trauma, slight or otherwise, which called attention of the patient to a nodule or a beginning pain. On the other hand, chronic irritation can be an etiologic factor. One of the best examples of this is the transformation of a nevus from a benign lesion to a melanotic sarcoma when located at the belt line or at a place where clothing may be a source of chronic irritation. This is different from the occasional production of squamous carcinoma of the lip by the irritation of a pipe stem, because the melanotic sarcoma required the presence of a certain type of nevus.

Intrinsic Factors. These factors result primarily from metabolism within the body and may be normal or abnormal states. The two important intrinsic factors are hormones and viruses (3), of which the latter may, on certain occasions, be extrinsic in origin.

HORMONES. Perhaps the first suggestion of relationship of hormones to production of cancer was the demonstration that the incidence of mammary cancer was higher in animals prevented from breeding than in breeding females of the same stock (Lathrop and Loeb, 1916). Lacassagne (9) was the first to induce mammary cancer in animals by injection of hormones; he did so by injecting a mixture of estrone, equilin, and equilenin (from the urine of a pregnant mare) into castrated male mice. However, there is no positive evidence that the administration of female sex hormones to women will induce cancer, although cancer of the male breast has been reported in men undergoing heavy stilbestrol therapy for carcinoma of the prostate (10). Sex hormones act in a synergistic way in producing experimental cancer, as shown by the demonstration of Strong (11), that neither estrone nor methylcholanthrene alone will induce mammary cancer in male mice of the C_3H and $C_{57}BL$ strain, but cancer is induced if the two agents are given simultaneously. When diethylstilbestrol is fed to male mice of the susceptible C_3H strain of mice, mammary tumors develop within 20 weeks after the initial administration (Shimkin and Grady, 12). Estrogen, when fed over a long period of time, may also induce the formation of testicular tumors. The experiments of Biskind and associates (13) constitute a good example of the carcinogenic effect of hormonal imbalance; they induced tumors in ovaries transplanted into the spleen of castrated rats. This may indicate that the liver possesses the ability to inactivate ovarian hormones or that the increased formation of pituitary gonadotrophin subsequent to castration is a potent causative factor. Kirkman and Bacon (14) report production of bilateral renal tumors in male hamsters after prolonged therapy with large quantities of diethylstilbestrol. Likewise, cancer of the bladder is produced in rats (associated with urinary calculi) if diethylstilbestrol pellets are planted subcutaneously (Dunning and associates, 15).

The above data indicate that there is a strong relationship between sex hormones and development of cancer in animals, but the evidence of such a relationship in the human being is much less pronounced. There is ample evidence that deprivation of male and sex hormones in human beings with advanced cancer exerts a favorable influence on regression of the tumor. This will be discussed later in this chapter and also in Chapter 35. Additional data may be found in the Symposium on Endocrinology of Neoplastic Diseases (16), by numerous authors.

Rats treated with pituitary growth hormone over long periods of time develop neo-

plasms of the lungs, lymphatic tissue, adrenals, and reproductive organs (17).

VIRUSES. The first demonstration that a virus may cause cancer was that of transmission of the chicken sarcoma by injection of cell-free extract of a tumor to another chicken (Rous, 1911). Leukosis can also be transmitted in fowls by cell-free plasma with the production of sarcomas as well as endotheliomas and myeloleukosis (Stubbs and Furth, 1935). In 1933, Shope demonstrated that the spontaneous papillomas of rabbits could be transmitted from one rabbit to another by injecting a cell-free extract of the tumor. Additional evidence of the virus theory, at least in animals is the work of Bittner (18) (1936), who showed that when offspring of a high tumor strain of mice were suckled by foster mothers of a low breast-tumor strain, the foster nursed mice showed a low tumor rate. These experiments indicated that the mothers of the high tumor strain transferred the tumor or, more accurately, its etiologic factor to her progeny; this agent must accordingly be a virus. It is found in all tissues of the body, is destroyed by heating at 65° F. for 30 minutes, and is filterable through a Berkefeld or Seitz filter.

Numerous workers have suggested that the etiologic cause of human cancer is a virus, but up-to-date proof is lacking. Stanley (19) has been a strong proponent of the virus etiology in the human being. Critics of the virus theory argue that, if a virus was the cause of human cancer, there would be more evidence of contagion and someone would surely have demonstrated it by this time. Stanley counters with the fact that many viruses are difficult to isolate. Furthermore, he calls to our attention the knowledge that the psittacosis virus can exist in a group of parrots and certain other birds for long periods of time without manifestations, but under crowded conditions the disease may suddenly break out with virulence. Also, certain potato viruses can be passed from generation to generation without causing apparent disease. Stanley states further that "We know that viruses can persist in their host for generations, in either an infectious or noninfectious form. We know that viruses may mutate to form new strains that cause different symptoms. We know that different carcinogenic agents can activate subinfections or latent viruses or prophages with consequent cellular destruction." Accordingly, Stanley contends that the persistence of a virus in man for years or generations without manifestations should not be regarded as unexpected or unusual. For these reasons, he insists that there is good evidence to indicate that the primary cause of cancer is a virus.

It is believed that certain carcinogenic agents are produced in the body by normal or abnormal metabolism. For example, there is good evidence that methylcholanthrene may arise from bile acids through abnormal metabolic processes.

Environmental Causes. Many of the environmental causes of cancer are extrinsic in type and some, including tar products such as encountered by chimney sweeps and workers in the coal tar industry, have therefore been discussed. However, these factors are discussed separately because they are such obvious and such important causes of cancer. Many of the agents identified as environmental causes represent industrial hazards.

OCCUPATIONAL CANCERS. There are numerous occupational cancers in addition to the tar cancers and chimney sweep cancers, both of which involve the skin. Workers in certain textile plants developed cancer of the scrotum, produced by the constant spray of mineral oil over them. Much of the evidence just mentioned was accumulated in Britain. In Basel, A. Mueller (1933) reports that in dye factories the incidence of bladder cancer was 33 times as frequent as in the normal population. This is the so-called "aniline cancer" presumed to be induced by the aromatic amines. In this type of cancer, β-naphthylamine has been incriminated by Hueper (20); it will produce bladder tumors in dogs. Asbestos, and certain metals, including chromates and nickel, will produce cancer of the lung (20).

Hueper has called attention to the fact that the latent periods of some of the tumors mentioned in the preceding paragraph vary from 1 to 50 years. The average for the tar cancers was 22 years; for the mineral oil cancers it was 50 to 54 years; for the carcinomas of the lung produced by asbestos, chromates, and

nickel it was 18, 15, and 22 years respectively. Other details of occupational cancer may be found in publications by Greenstein (3) and Vorwald (21).

RADIATION. This factor has long been known to be a cause of cancer. There are numerous types, but the simplest is sunlight; this relationship has been known for years. It has been shown (Findley, 1928) that the inciting factor in sunlight is most likely ultraviolet radiation, since experimental cancer can be produced by the latter factor.

There is much evidence to indicate that *radioactive substances* can produce cancer. For example, cancer of the lung has been described in the workers in mines of the Joachimsthal and Schneeberg mountains, which at present are being worked for uranium ore (22). For centuries, the death rate from cancer of the lungs has been so high there that it has been estimated that 90 per cent of all cancers in these miners originates in the lungs (23). It has been known for decades that osteogenic sarcoma is common in radium dial painters (Martland, 1931). It is also known that plutonium (Pu), strontium (Sr^{90}), and phosphorus (P^{32}) will produce bone tumors and occasionally lymphomas in mice.

Radiation from radioactive material will also produce leukemia. For example, in the survivors at Hiroshima and Nagasaki the incidence of leukemia in survivors 2,000 or more meters from the point of explosion was three times the control rate, but for people 1,000 meters or less from the point of explosion it was 20 times the control rate (22).

It is well known that frequent *exposure to x-ray* is apt to produce a carcinoma. The most common examples of this are found in physicians who use fluoroscopic x-ray examination without proper protection of the hands. Many physicians have lost part of the hand or had to have resection of the skin of the dorsum of the hand, with skin graft, to eliminate squamous carcinoma, which is much more apt to develop following numerous exposures of small doses than after one or two massive doses of x-ray therapy. A minimum of five years is required for this transformation to take place. Cancer will also develop in the ulcer induced by an x-ray burn. In such cases there is no assurance that the x-ray exposure was the cause of the cancer since similar neoplasms (i.e., squamous cell carcinoma) will develop, within 10 to 30 years, in a neglected ulcer produced by a thermal burn (Fig. 2). Leukemia may also be induced by exposure to x-ray therapy; it

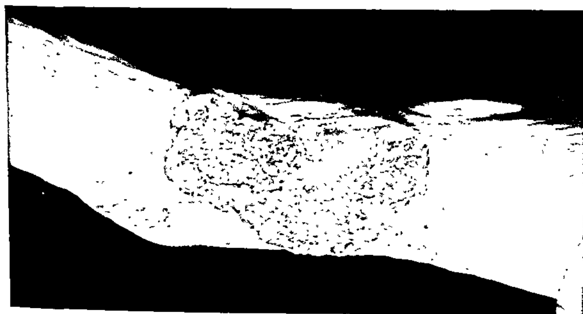


Fig. 2. Squamous carcinoma in a burn of the arm. The patient had a third-degree burn 20 years ago. The granulating area had never completely healed. One year ago the ulcer began to enlarge and the edges became hyperplastic. Biopsy was positive.

is 1.7 times more common in physicians than lay individuals (Henshaw, 1944). The above data may worry us additionally lest exposure to x-ray without a burn result in an increased incidence of cancer. Actually, Spitz and Higginbotham (24) have reported osteogenic sarcomas in patients given large doses of x-rays. However, the incidence is not high enough to contraindicate the use of x-ray therapy.

CIGARETTE SMOKING. Of all the carcinogenic factors, cigarette smoking is receiving the most attention at the present time. During the past several years numerous investigators, in different countries, have studied the relationship between cigarette smoking and cancer of the lung. Practically all of them have arrived at the same conclusion; namely, that cigarette smoking increases the chance of developing lung carcinoma, particularly in men. Wynder and Graham (25) were among the first to report. In Britain, Doll and Hill (26) arrived at the same conclusion. Tar obtained by condensation of the cigarette smoke will produce cancer when painted on the skin of mice (27, 28). In Wynder and Graham's experiments, the cancer did not develop until 71 weeks (half the mouse life span) had elapsed since start of the painting. Chemical analysis of the smoke yields 3,4-benzpyrene (29, 30). There has been considerable argument as to whether the carcinogenic agents are in the tobacco or in the cigarette paper, particularly since chemical analysis reveals 3,4-benzpyrene in the smoke of cigarette paper as well as of the tobacco (30). However, there is no agreement that there is enough benzpyrene in the condensate of cigarette smoke to produce the cancer in the animal experiments.

In the analysis of a study carried out by the American Cancer Society on 190,000 men over a 44-month period, Hammond and Horn (31) report that, in men, cigarette smoking increases the death rate from numerous causes, particularly cancer of the lung.

The death rate from cancer of the lung in men who smoked half a pack of cigarettes per day was 7.3 times as great as in nonsmokers; the rates for men smoking half to one pack, one to two packs, and two or more packs per day were 8.4 times, 18.0 times, and 21.0 times greater respectively than the rate for nonsmokers. Surely this sharp increase in deaths from cancer of the lung in the men smoking cigarettes, with an increasing mortality as the smoking increases, would convince anyone that cigarette smoking increases the probability of contracting cancer of the lung. The death rate in cigar smokers was about the same as in nonsmokers; in pipe smokers it was about 3 times as high as in nonsmokers. The above figures exclude adenocarcinoma of the lung, the incidence of which is presumably not related to smoking.

The death rate from cancer of the kidney was 1.58 times higher in cigarette smokers than in nonsmokers, from cancer of the prostate it was 1.75 times higher, and from cancer of the bladder 2.17 times higher than in nonsmokers. The death rate from cancer of the colon and rectum was the same in smokers as it was in nonsmokers, but slightly higher from cancer of the pancreas (1.5 times) and stomach (1.6 times). However, the death rate from liver and gallbladder cancer was 4.5 times higher in cigarette smokers than in nonsmokers.

Of considerable interest, but unrelated to the subject of this chapter, was the fact that the death rate from coronary disease was 2.41 times greater in men smoking two or more packs of cigarettes per day than it was in nonsmokers. In the groups smoking less, the death rate decreased in a manner parallel to the decrease in smoking.

In general, the death rate from cancer of the lung of men in large cities was greater than in men living in rural areas, when groups with equal smoking habits were compared. This could probably be explained on the basis that noxious gases and smoke from automobiles, industrial plants, and so forth, may also be factors in increasing the incidence of cancer of the lung. In fact, Kotin (32) reports that painting the skin of animals with foreign material obtained from the atmosphere of a large industrial city produced cancer. From his study of the American Cancer Society data, Hammond (33) estimates that 31 per cent of the deaths from cancer of the lung were due to air pollution. From studies

in Liverpool, Stocks and Campbell (34) estimated that about 35 per cent of the deaths from cancer of the lung resulted from air pollution, a figure remarkably close to Hammond's estimate.

MISCELLANEOUS FACTORS. There are numerous other environmental causes not related to occupation, e.g., radiation or smoking, which we shall identify only as environmental. *Smegma* appears to be an important carcinogen insofar as carcinoma of the penis is extremely rare in circumcised men, and carcinoma of the cervix is rare in groups which practice circumcision. Moreover, cervical cancer has been produced in mice by the local application of smegma. Recently, it has been shown that heavy consumption of *whisky* is an important factor in the development of carcinoma of the larynx (35) and possibly of the esophagus. Under such circumstances, it may act as a cocarcinogen. *Schistosomiasis* is an important factor in the production of bladder cancer. In Egypt (36), there is less evidence that the Schistosoma parasite is a causative factor of cancer of the liver. Data from India (37) indicates that betel nut chewing increases the incidence of cancer of the oral cavity and hypopharynx. However, it is not clear whether or not betel nut alone will produce cancer, since tobacco is usually an ingredient of the quid.

MECHANISMS AND AVENUES OF CANCER RESEARCH

Before the end of the last century research in cancer was very limited and unscientific. This was due in part to the fact that no promising mechanisms were available, there were no animal tumors to use, and significant experiments on the human being were obviously not feasible. Since the beginning of the present century numerous mechanisms for performing research have been developed. The amount of experimentation and publications have accumulated in such volume that no one person can possibly keep up with the data. This has given rise to the writing of numerous books and monographs which help greatly in supplying information to each worker in his field. Cancer research has attracted brilliant scientists, of whom many have made great contributions. However, as Greenstein (3) says "for some odd reason cancer research has been the graveyard of many a scientific reputation." Nevertheless, cancer will continue to present a challenge and entice good experimentalists, largely because the stakes are high and the reward great —professionally, not financially—for fine contributions. All of us know that the person who discovers the cure or true cause of cancer will probably receive an acclaim unequaled in the annals of medical history. Many vital discoveries have been made in cancer research, but we are still so short of the final goal that we must assume a still greater accumulation of knowledge will be required.

The first great step in the development of a mechanism for research was the successful transplantation of a tumor by Hanau from one rat (wild) to another at the end of the last century. The later development of a good experimental animal—the albino rat—by Chicago scientists (Slye, Wistar, and associates) was another very important advancement. The discovery of the x-ray and radium emanation at the turn of the century supplied us with a good therapeutic tool. A few years later, various strains of mice were developed which had certain characteristics regarding susceptibility and immunity to certain tumors. L. C. Strong and C. C. Little have been important pioneers in this field. Special credit should be extended the latter for his influence in developing the laboratory at Bar Harbor, Maine, which supplies scientists with animals of various strains. As stated previously, the first successful production of an animal tumor (by painting tar on the ears of rabbits for 15 months) by the Japanese scientists Yamagiwa and Ichikawa (5) represents a very important milestone.

Progress made in the past several years indicates that the chemical treatment of cancer, including hormones and antibodies, may offer hope of being very effective. One of the first examples of this mechanism was Coley's toxin (1893), which was effective on only an occasional case, primarily sarcoma. The first effective use of hormones was reported by Huggins and associates (37), although it had been known for decades that castration was often effectual in causing regression of carci-

is 1.7 times more common in physicians than lay individuals (Henshaw, 1944). The above data may worry us additionally lest exposure to x-ray without a burn result in an increased incidence of cancer. Actually, Spitz and Higginbotham (24) have reported osteogenic sarcomas in patients given large doses of x-rays. However, the incidence is not high enough to contraindicate the use of x-ray therapy.

Cigarette Smoking. Of all the carcinogenic factors, cigarette smoking is receiving the most attention at the present time. During the past several years numerous investigators, in different countries, have studied the relationship between cigarette smoking and cancer of the lung. Practically all of them have arrived at the same conclusion; namely, that cigarette smoking increases the chance of developing lung carcinoma, particularly in men. Wynder and Graham (25) were among the first to report. In Britain, Doll and Hill (26) arrived at the same conclusion. Tar obtained by condensation of the cigarette smoke will produce cancer when painted on the skin of mice (27, 28). In Wynder and Graham's experiments, the cancer did not develop until 71 weeks (half the mouse life span) had elapsed since start of the painting. Chemical analysis of the smoke yields 3,4-benzpyrene (29, 30). There has been considerable argument as to whether the carcinogenic agents are in the tobacco or in the cigarette paper, particularly since chemical analysis reveals 3,4-benzpyrene in the smoke of cigarette paper as well as of the tobacco (30). However, there is no agreement that there is enough benzpyrene in the condensate of cigarette smoke to produce the cancer in the animal experiments.

In the analysis of a study carried out by the American Cancer Society on 190,000 men over a 44-month period, Hammond and Horn (31) report that, in men, cigarette smoking increases the death rate from numerous causes, particularly cancer of the lung.

The death rate from cancer of the lung in men who smoked half a pack of cigarettes per day was 7.3 times as great as in nonsmokers; the rates for men smoking half to one pack, one to two packs, and two or more packs per day were 8.4 times, 18.0 times, and 21.0 times greater respectively than the rate for nonsmokers. Surely this sharp increase in deaths from cancer of the lung in the men smoking cigarettes, with an increasing mortality as the smoking increases, would convince anyone that cigarette smoking increases the probability of contracting cancer of the lung. The death rate in cigar smokers was about the same as in nonsmokers; in pipe smokers it was about 3 times as high as in nonsmokers. The above figures exclude adenocarcinoma of the lung, the incidence of which is presumably not related to smoking.

The death rate from cancer of the kidney was 1.58 times higher in cigarette smokers than in nonsmokers, from cancer of the prostate it was 1.75 times higher, and from cancer of the bladder 2.17 times higher than in nonsmokers. The death rate from cancer of the colon and rectum was the same in smokers as it was in nonsmokers, but slightly higher from cancer of the pancreas (1.5 times) and stomach (1.6 times). However, the death rate from liver and gallbladder cancer was 4.5 times higher in cigarette smokers than in nonsmokers.

Of considerable interest, but unrelated to the subject of this chapter, was the fact that the death rate from coronary disease was 2.41 times greater in men smoking two or more packs of cigarettes per day than it was in nonsmokers. In the groups smoking less, the death rate decreased in a manner parallel to the decrease in smoking.

In general, the death rate from cancer of the lung of men in large cities was greater than in men living in rural areas, when groups with equal smoking habits were compared. This could probably be explained on the basis that noxious gases and smoke from automobiles, industrial plants, and so forth, may also be factors in increasing the incidence of cancer of the lung. In fact, Kotin (32) reports that painting the skin of animals with foreign material obtained from the atmosphere of a large industrial city produced cancer. From his study of the American Cancer Society data, Hammond (33) estimates that 31 per cent of the deaths from cancer of the lung were due to air pollution. From studies

in Liverpool, Stocks and Campbell (34) estimated that about 35 per cent of the deaths from cancer of the lung resulted from air pollution, a figure remarkably close to Hammond's estimate.

Miscellaneous Factors. There are numerous other environmental causes not related to occupation, e.g., radiation or smoking, which we shall identify only as environmental. *Smegma* appears to be an important carcinogen insofar as carcinoma of the penis is extremely rare in circumcised men, and carcinoma of the cervix is rare in groups which practice circumcision. Moreover, cervical cancer has been produced in mice by the local application of smegma. Recently, it has been shown that heavy consumption of *whisky* is an important factor in the development of carcinoma of the larynx (35) and possibly of the esophagus. Under such circumstances, it may act as a cocarcinogen. *Schistosomiasis* is an important factor in the production of bladder cancer. In Egypt (36), there is less evidence that the Schistosoma parasite is a causative factor of cancer of the liver. Data from India (37) indicates that betel nut chewing increases the incidence of cancer of the oral cavity and hypopharynx. However, it is not clear whether or not betel nut alone will produce cancer, since tobacco is usually an ingredient of the quid.

MECHANISMS AND AVENUES OF CANCER RESEARCH

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noma of the prostate and ovary. In 1946, Goodman, Gilman, and associates (38) reported the beneficial use of nitrogen mustard in human cancer.

It is well known that the effects of various types of cancers on animals, and the effects of various anticancer agents on the cancers of animals, cannot be transferred literally to cancer in man. The growth of human tumors in animals would allow experimentation, with results which would be much more applicable to human cancer. Under ordinary circumstances human tumors will not grow in animals. However, in 1952, Greene (39) reported that human tumors could be grown in the anterior chamber of the guinea pig eye. He reported that the tumor grew in 65 cases and failed in 58; however, not all workers have been able to obtain a growth in such a high percentage of cases. The discovery by Toolan (40) that treatment of animals with cortisone or x-irradiation will condition animals so that human tumors will grow when transplanted subcutaneously (e.g., into the pouch tissue of a hamster) offers a better mechanism of studying the effects of various agents on tumors which, at least, were derived from the human being.

SYSTEMIC EFFECT OF CANCER ON THE HUMAN BODY

Surprisingly few alterations are produced by cancer in the body (except in late cancer) other than those which can be explained on the basis of changes induced by pathologic processes itself; e.g., loss of plasma and blood from an ulcerating tumor. Numerous workers have discussed the possibility of a cancer "toxin," but as yet there is no evidence that one exists. However, Graham and Graham (40a) have presented evidence that antibodies exist. Of 48 cancer patients tested for antibodies to their own tumor by complement fixation technic, 12 had a titer of 1:16 to 1:28. The majority of patients not showing antibodies had far advanced cancer.

Loss of weight is a fairly constant symptom. On most occasions it is caused by lack of intake of food; this lack of intake may be caused by anorexia itself or to pain. Loss of weight is pronounced in patients with oral cancer, due primarily to difficulty or pain with swallowing. Loss of plasma and blood from an ulcerating tumor may also produce weight loss. In carcinoma of the stomach weight loss is often the first symptom; invariably in such early cases, lack of intake due to anorexia or postprandial distress is the cause.

Hypoproteinemia is a fairly common manifestation of cancer. Usually it is due to loss of plasma and blood from an ulcerating tumor. In the later stages of the disease, when metastases are growing to considerable size, it can be explained by the transfer of nitrogen from normal body tissue to cancerous tissue, a natural process which is almost bound to exist at this stage because intake is usually insufficient to furnish adequate nitrogen to both tissues. On other occasions, the hypoproteinemia appears to be caused by liver dysfunction, since the synthesis of plasma protein is carried on primarily by the liver.

Liver dysfunction has been noted by Abels and associates (41) in a high percentage of patients with gastrointestinal cancer. Their studies include data on plasma prothrombin, serum protein, vitamin A, urinary excretion of glucuronates, and metabolism of urobilinogen, serum cholesterol, and serum cholesterol esters. During the second stage of tumor growth the liver enlarges, although in the ante-mortem stage of the disease there is a decrease in liver weight (42). The lipids in the liver increase.

There are changes in the level of many *enzymes*, primarily a decrease. One of the enzymes most constantly lowered in almost all types of animals with experimental cancer is liver catalase. It has been studied by numerous workers; the data accumulated by these scientists have been summarized by Greenstein (3). Other enzymes, including hepatic and renal d-amino acid oxidase, and esterase, are also lowered. Reduction of the latter may be due to hepatic insufficiency because it is synthesized by the liver, the functions of which often are impaired by cancer. The presence of inhibitors of the trypsin enzymes—including trypsin, chymotrypsin, plasmin, and rennin—in the serum is well established, insofar as relatively small quantities of serum will inhibit the enzymes (43).

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PSYCHOLOGIC EFFECTS OF CANCER

The public is aware of the serious consequences of cancer, and the contraction of the disease is accordingly associated with a variable amount of emotional shock. However, a great deal of the shock sustained by the cancer patient is related to ignorance. A surprisingly large percentage of patients consider cancer a hopeless disease, not realizing that if the lesion is treated early the chance of a cure is quite good, providing the proper treatment (primarily, operation or radiation) is carried out. Another fear experienced by many patients is the supposition that, even if the cancer is treated successfully, a serious disability may result from the treatment; most of these are, of course, unfounded. Still another fear possessed very often by the patient, as well as by his family, is that the disease is contagious and will be transmitted to other members of the family. The contagious element is entirely unfounded; only very seldom does there appear to be a slight hereditary trait.

Since a major portion of the worry created by the patient's fear that he may have cancer is related to lack of information about diagnosis, methods of therapy, prognosis, and so forth, it would appear that a campaign of lay education would be desirable. Numerous agencies are aware of this, and one of them particularly, the American Cancer Society (with its numerous divisions), conducts a continuous campaign to educate lay people as well as doctors. These mechanisms of education for lay people are carried out in numerous ways, including lectures, pamphlets, movies, and television shows. One of the most effective single factors is a movie entitled, "Self Examination of the Breast for Women." Invariably, when this movie is shown to an audience of a few hundred women, several of the audience report to physicians' offices during the next few days with breast tumors, a few of which are malignant; these cancers are invariably early ones in which prognosis is very good with prompt proper treatment. A few physicians claim that such a campaign will instill so much fear in the minds of lay people that it will do more harm than good. The author is convinced this is not so, believing that fear of cancer created in this way can be allayed very quickly by a thorough negative examination by a physician, followed by a sincere assuring talk about the problem. If the patient still has cancer phobia after a negative examination and an assuring talk with his or her physician, it is the author's opinion that a phobia of some

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other kind would develop if cancer phobia were obliterated. In a questionnaire survey conducted by Samp and Curreri (48) it was noted that only 3.5 per cent of 560 patients interviewed stated that the educational campaign conducted by the American Cancer Society and other agencies was "too much." Many of the individuals interviewed thought the campaign initially made them fear cancer, but 97 per cent of those replying to that question thought the explanation offered by the educational campaign lessened the fear. After all, we must instill a certain degree of fear in the minds of people to get them to go to a physician. Too often indeed, when we ask the patient with an inoperable or incurable cancer why he or she waited so long the answer is, "Well, it was giving me no pain, and I did not think it was serious." We must continually emphasize that lack of pain in a tumor nodule does not eliminate cancer.

One of the most important points in the consideration of cancer and the patient is the question as to whether or not the patient should be told he has a cancer. There has been considerable argument on this point. In the author's opinion the question cannot be answered "Yes" or "No." There can be no question that certain patients sustain no emotional imbalance whatsoever upon hearing the news, along with proper information, whereas other patients collapse to the point of a psychiatric complication. Accordingly, in the author's opinion, the physician must know his patient, telling those who can tolerate the news and not telling those who might be seriously disturbed emotionally by the knowledge that they have cancer. Unfortunately, one cannot assume that the patient who requests he be told has sufficient emotional stability to withstand the news; in fact, the patient who insists loudly and strongly that he be told is often the one who will collapse the most completely when he is told. One can withhold the exact information from the patient with very few exceptions by explaining that he has a tumor. When asked if this is cancer, the honest reply can be that it is a type of cancer, but one in which you expect good results if that is the case. If you cannot truthfully expect good results, the patient and family invariably receive great comfort from the statement that "we" should be hopeful, because occasionally such tumors, though appearing very serious, sometimes grow very slowly and, in fact, now and then disappear entirely. There is good evidence that this is true (49). In any event, some responsible member of the family must be told the exact diagnosis and expected prognosis, even though the physician chooses to withhold the correct diagnosis from the patient. If the patient is to have a permanent colostomy, he must be told this before operation and the entire situation explained to him, assuring him that at first there may be considerable emotional disturbance from the colostomy, but that with practically no exceptions the patient adjusts completely to it. Often, it will be necessary for the patient to talk to someone with a permanent colostomy before he will sign an operative permit.

It must also be emphasized that the physician must not neglect the terminal cancer patient simply because he cannot cure him. Often, proper psychologic aid afforded by the physician's attention and time will be sufficient to make life tolerable for the patient and his family. Too often, indeed, the physician neglects the patient with terminal cancer. He needs your help and you must not ignore him. Likewise, as the patient's physician you should encourage him to seek comfort in religion; sometimes this must be done very cautiously and skillfully lest the patient think you are deliberately preparing him for the great beyond. Serious emotional imbalance in patients who are very unstable has been discussed by Sutherland (50).

MECHANISMS OF SPREAD OF CANCER

The physician cannot treat a tumor intelligently unless he is familiar with the usual methods of spread. It must be emphasized that no two tumors behave exactly alike, even though they have the same appearance and are of the same type. Accordingly, we must treat each tumor as an individual problem, even though we realize the methods of spread will vary. In general, there are four major methods of spread (but not all tumors spread by all four mechanisms): 1. by lymphatics; 2. by local implantation; 3. by contiguity through tissue planes; and 4. by venous emboli.

Lymphatic Metastases. The classical work done by the British surgeon, W. Sampson Handley, many decades ago, was very helpful to the surgeon in planning the operative removal of malignant tumors and served to stimulate additional work which has been carried on by numerous investigators (51). Certain types of tumors spread by lymphatics more actively than others; the cells travel in the lymphatic channels to lymph nodes. When a lymph node becomes blocked with tumor cells, there is a tendency for additional cells to travel onward to more distant nodes through collaterals. In addition, cells will travel from one node to another, usually in the direction of lymph flow, rarely against it. If surgical incision extends beyond all of the tumor and involved nodes, a cure can be expected *unless venous metastases have already taken place*. It must be remembered that microscopic metastases may be present in lymph nodes beyond the extent of excision and may not be palpable.

Extension by Contiguity. Practically all malignant tumors spread by this mechanism, some faster than others. Obviously, practically any tissue may be invaded, depending upon the location of the tumor. The tumors which invade most extensively by contiguity through tissue planes, with formation of bulky tumors, are not necessarily the most dangerous, and vice versa. Often large bulky tumors are curable, and small, seemingly local ones may metastasize (via veins) extensively. Accordingly, tumors which have spread extensively by contiguity should, in general, be operated on unless their excision involves removal of vital tissue necessary to life.

Local Implantation. One of the best examples of implantation of malignant cells is a *recurrence developing in a wound* a few weeks or months after excision of a malignant tumor. If the tumor was inadequately excised, the recurrence may, of course, represent a continued growth from the original tumor. This type of recurrence may not be preventable, simply because the tumor was inoperable. We are much more concerned about the recurrence in the wound after an operation during which the tumor was widely removed with no obvious primary or secondary tumor remaining (Figs. 3, 4). These are theoretically preventable and result from too much manipulation of the tumor or from cutting across a vein or lymphatic which happened to contain some viable cancer cells. In the latter case, irrigation of the wound with the proper chemical may remove the vast majority of these cells. Actually, cancer cells can be found in the wound washings at the completion of an operation. In a study of 120 patients having radical operation for cancer, Hilberg and associates (52) found cancer cells in the wound washings in 26 per cent and doubtful cells in an additional 14 per cent. Very significant in their study is the fact that in 30 per cent of cases in which all gross tumor was removed the wound washings were positive.

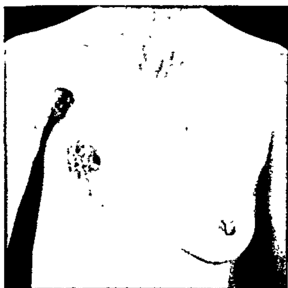


Fig. 3. Recurrent carcinoma, most likely resulting from implantation. The patient had a radical mastectomy five years ago for an adenocarcinoma of the breast. Six months ago she noted a small nodule growing in the scar of the incision made then. It was removed widely and a skin graft applied. (After Cole et al. Bull. N.Y. Acad. Med.)

A few years ago, three different groups (53, 54, 55) independently became alarmed over the high incidence of *local recurrence at the suture line* following resection of the colon for carcinoma. All three groups concluded that implantation was the most logical explanation for most of the recurrences, and recommended procedures, as discussed later, to prevent or minimize that complication. The best explanation for this type of implantation is contamination of the suture

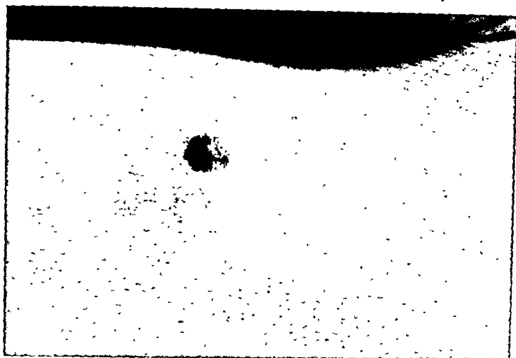


Fig. 4. Recurrent melanoma in the scar of a biopsy. Four months previously a subcutaneous nodule of the arm was removed for biopsy. Microscopic examination revealed a metastasis from a melanoma originating elsewhere.

line with loose cells from the operative field and their transplantation into the wall as the anastomosis is being performed. At least, there is fairly good evidence that the recurrence is secondary to implantation on some occasions. For example, in a series of 11 patients with recurrence at the suture line following resection of the colon, Fleischner and Berenberg (56) found a silk suture in the recurrent tumor in three cases; this phenomenon has been reported by others (57).

Innumerable types of implantation have been reported; they have been discussed by Ackerman and Wheat (57) and Cole and associates (58).

Venous Spread. For many years, pathologists have called attention to the invasion of veins within the tumor—especially of the rectum and colon—but clinicians have not attached the proper importance to this finding. For example, lymph node metastases are serious; so is the local growth of the tumor, by contiguity; but the *lethal factor is the venous invasion*. Accordingly, it deserves intense study.

Grinnell (59) found invasion of veins, microscopically, within the tumor in 36 per cent of patients with carcinoma of the rectum and in 33 per cent of patients with carcinoma of the colon; Brown and Warren (60) report it in 61 per cent of patients with carcinoma of the rectum. The study by the latter authors was made in autopsy specimen, thereby accounting for the higher incidence.

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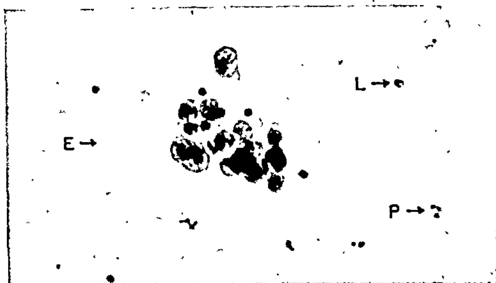


Fig. 5. Malignant cells isolated from the peripheral blood of a patient with an advanced carcinoma of the breast. Compare the clump of malignant cells with L, the lymphocytes, P, the polynuclear leukocytes, and E, the erythrocytes.

and in 70 per cent of 31 patients with cancer of the colon. In his series, cells were found in 0 per cent of patients with Grade I tumors, in 35 per cent of patients with Grade II tumors, in 78 per cent of patients with Grade III tumors, and in 100 per cent of patients with Grade IV tumors. He reports finding cancer cells in the systemic blood in 13 per cent of 79 patients with operable cancer, and in 50 per cent of 14 patients with inoperable tumors. With reasonable care, these cells can be identified and differentiated quite accurately from normal blood cells (Fig. 5), as shown by Roberts and associates and others (65, 66).

DIAGNOSTIC METHODS

The routine methods in history taking and physical examination are discussed in detail in Chapter 2. Moreover, various diagnostic methods have been described with the surgical lesions as they have been presented. Accordingly, a complete description of methods here would be superfluous. However, there are certain features which are peculiar to cancer; these will be emphasized. Fortunately, the majority of cancers are visible or palpable by digital examination, including vaginal and rectal examination. However, many of those not palpable are extremely difficult to diagnose.

History. There are very few points in the history which are diagnostic of cancer as a disease itself. Often, indeed, a history of loss of weight and weakness is encountered in many types of cancer (e.g., stomach), but diabetes, tuberculosis, and many other diseases will produce the same symptoms. Pain is so commonly absent in early cancer that it is of little help diagnostically except in a reverse manner; e.g., early cancer of the breast rarely produces pain, whereas chronic cystic mastitis with few positive findings may produce considerable pain.

Abnormal bleeding from any orifice is often, indeed, due to cancer. This is particularly true of rectal bleeding if the fresh bleeding of hemorrhoids is excluded. Occult blood may be just as helpful as gross bleeding, particularly if it is present constantly and the patient is on a meat-free diet.

The history of a brain tumor may be quite diagnostic. For example, if a patient complains of headache and disturbances in the visual fields, one must consider the presence of brain tumor until proven otherwise.

Inspection. The lesions visible by inspection alone are primarily the epitheliomas of the skin and mucous membranes of the oral cavity. Cancer of the cervix and rectum is diagnosable by digital examination; with the aid of the vaginal speculum and proctoscope they can be visualized. Most epitheliomas of the skin will be ulcerated. Malignant nodules

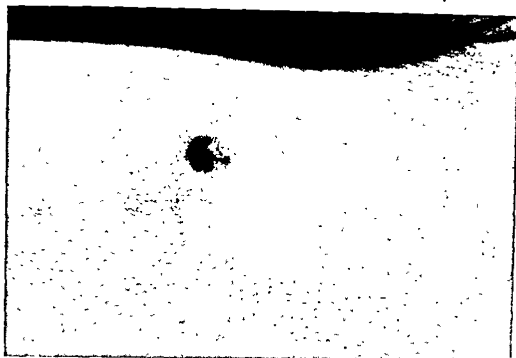


Fig. 4. Recurrent melanoma in the scar of a biopsy. Four months previously a subcutaneous nodule of the arm was removed for biopsy. Microscopic examination revealed a metastasis from a melanoma originating elsewhere.

line with loose cells from the operative field and their transplantation into the wall as the anastomosis is being performed. At least, there is fairly good evidence that the recurrence is secondary to implantation on some occasions. For example, in a series of 11 patients with recurrence at the suture line following resection of the colon, Fleischner and Berenberg (56) found a silk suture in the recurrent tumor in three cases; this phenomenon has been reported by others (57).

Innumerable types of implantation have been reported; they have been discussed by Ackerman and Wheat (57) and Cole and associates (58).

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Fig. 6. Early carcinoma of the stomach (pylorus). This lesion was so small it was demonstrable only by taking an oblique view. Symptoms consisted of dyspepsia of three months' duration.

colon), the surgeon does not need to rely upon a biopsy. However, an indurated lesion in the sigmoid associated with diverticula might be a cancer or diverticulitis. Under such circumstances, he may resect the lesion and wait for a diagnosis from the pathologist before he proceeds with a radical resection. On other occasions (e.g., cancer of the middle or upper third of the esophagus), few surgeons indeed will proceed with the usual cancer operation before biopsy confirmation because the mortality of such operations is high and he does not wish to submit the patient with a benign lesion to such a high mortality rate.

It is readily understandable that the surgeon would like to have a positive diagnosis in every patient with cancer before he proceeds with the operation. However, he is confronted with the question as to how often biopsy will disseminate the cancer. It appears that, in ulcerating lesions of the rectum, a biopsy which is taken from the mucosal surface should not induce any dissemination. Unquestionably, venous dissemination is much more dangerous than lymphatic, since the former travels far beyond the limits of the resection. Accordingly, biopsy in epitheliomas, which rarely metastasizes by vein, will be quite safe.

However, in tumors which are vascular and notoriously metastasize by vein (e.g., tumors of the breast, thyroid, and pancreas), biopsy may not be innocuous. Already we are learning that a needle biopsy may be dangerous. Ackerman and Wheat (57) have reported many instances in which the tumor grew out alongside the needle tract. Davis (67), studying patients in the Illinois Research Hospital clinic, found that the five-year survival rate in patients with cancer of the breast who had aspiration or incisional biopsy 1 to 20 days before radical resection was much lower than that for the entire group. The five-year survival rate for those having excisional biopsy was about the same as for

in the subcutaneous tissue beneath the skin are apt to be metastatic, commonly melanotic sarcomas, the pigment of which can often be seen through the skin. Lesions of the oral cavity will be visible by using a flashlight and tongue blade, but those in the hypopharynx and larynx will usually require the use of laryngoscopic mirrors. Many tumors reveal themselves as abnormalities in shape and conformity of various parts of the body, e.g., sarcoma of the bone.

The ulcerations of cancer, regardless of the type of lesion, are fairly characteristic. This is true of cancers of the skin, the mucous membranes of the oral cavity, and the gastrointestinal tract. The surface is seldom smooth, being either granular or with a cauliflowerlike nodularity. The ulcerations bleed readily. The less nodular portions of the granulating surface usually have a granular appearance; these granules are either gray or grayish yellow in color.

Palpation. Palpation may reveal a nodule or nodules which may be benign or malignant. Most malignant ones are hard, but not stony hard. Most primary lesions will have an irregular surface. On the other hand, metastases to lymph nodes may have a fairly smooth surface. Very few malignant lesions are acutely tender. Superficial nodules can sometimes be diagnosed correctly as malignant nodules, usually of the metastatic type. Lipomas are lobulated and softer than malignant nodules. Lymphomatous nodules are usually quite soft and, at times, so vascular and cellular that they appear fluctuant. Fixation of the mass is usually indicative of malignancy, although inflammation can produce this immobility.

X-Ray Examination. The x-ray is extremely helpful in the diagnosis of malignant disease, and, in fact, the clinician could not get along without it. On innumerable occasions, the x-ray is the deciding factor.

Plain x-ray films may reveal destructive lesions in the bone or cancer of the lung. A shadow of a malignant tumor on a plain film may be seen, but the shadow alone gives us no lead as to whether it is benign or malignant.

Fluoroscopic examination is often able to make a positive diagnosis, whereas without it differentiation would be very difficult. Cancers of the hepatic flexure, splenic flexure, and certain parts of the stomach often would not be diagnosable without the fluoroscope (utilizing barium as a contrast media).

The use of *barium as a contrast* media is extremely helpful in diagnosis. In fact, the x-ray has perhaps reached its peak of diagnostic accuracy in cancer of the gastrointestinal tract. In the stomach, the x-ray is very accurate (Fig. 6) except in the malignant ulcers which often cannot be identified even with the naked eye. For the colon, the barium enema is a very accurate diagnostic mechanism, except that in cancer of the rectosigmoid area the lesion is often hard to demonstrate.

Delineation of the *kidney outline with opaque media* is extremely valuable in diagnosing renal tumors. As described in Chapter 41, this may be achieved by intravenous or retrograde urography. The x-ray is not of much aid in diagnosing *cancer of the gallbladder* primarily because the gallbladder is usually badly diseased, casting no shadow with oral cholecystography (or even intravenous cholecystography, cholegrafin). Stones are usually present with cancer of the gallbladder, but the vast majority of stones are not associated with cancer. The important characteristics of *sinuses* and *fistulas*, including particularly their connections, can be well identified by the injection of such opaque substances as diodrast and hippuran into them. However, the outline of the sinus or fistula in itself will rarely be helpful in determining which is associated with cancer.

Laboratory Tests. X-ray examination, as described above, may be classified as a laboratory test and is extremely helpful. Numerous laboratory tests, as described in Chapter 3, will be helpful in diagnosing the secondary effects of cancer (e.g., hypoproteinemia and occult blood in the stool) but to date there is no specific test for cancer.

Biopsy. Microscopic examination of tissue is perhaps the most accurate mechanism of all in the diagnosis of cancer. True enough, the percentage of accuracy is dependent upon the skill of the pathologist. However, even a good pathologist is helpless without an adequate biopsy taken from the proper area of the lesion.

For certain lesions (e.g., carcinoma of the

tron, with x-ray beam and electron beam; 4. linear accelerator; 5. synchroton; and 6. isotopes. Details of the type of ray and the application of the various machines or agents have been discussed by Laughlin (69).

Experience has taught us that radiation is fairly effective against certain tumors and not others. For example, x-ray, commonly with 250,000 electron volts capacity, is very effective in cancer of the lip and often is used as the sole method of treatment in such cancers. It is also quite effective in numerous types of lymphomas (especially Hodgkin's disease), cancer of the cervix, and many others. In general, x-ray therapy is much less effective against metastases than against the primary. It is practically ineffective against all cancers of the gastrointestinal tract. The betatron, which develops 20,000,000 or more electron volts, has greater penetrating power without skin reaction. It accordingly is useful in treating deep lesions such as carcinoma of the esophagus. The linear accelerator, which develops at present up to 50,000,000 electron volts, and the synchroton, which develops even more (70,000,000 electron volts), may have still greater advantages, but clinical experience with them is still limited.

Numerous isotopes—including I^{131} (iodine), P^{32} (phosphorus), Au^{198} (gold), Co^{60} (cobalt), Ta^{182} (tantalum), Ir^{192} (iridium), and Br^{82} (bromine)—are being used, but experience with the last four is quite meager. I^{131} is used primarily for cancer of the thyroid, but less than half of the carcinomas of the cancerous thyroids will pick up the iodine even when stimulated with TSH (thyroid stimulating hormone). Au^{198} is being used in the treatment of cancer of the prostate and is also used in the peritoneal cavity at the end of an operation to "kill" tiny implants or displaced cells. P^{32} has been used in the treatment of leukemia, carcinoma of the breast, and certain other tumors.

Prophylactic or Adjuvant Therapy. Operative technic has developed to a degree approaching its maximum efficiency, yet a large number of patients having operations of the curative type develop recurrence in spite of surgery. Accordingly, we must seek other mechanisms of improving results. One of the obstacles in obtaining good results is the failure to have the patient report to the physician before his condition becomes inoperable or hopeless. A continual educational campaign must be maintained to improve this situation.

It is very important that when patients with palpable cancers are examined, the mass should be examined very gently, and by as few individuals as possible. Rough handling of the tumor unquestionably gives rise to lymphatic and particularly to venous dissemination. A common error made in clinical practice in the operating room is the use of soap and water preparation in patients with a palpable malignant tumor, particularly cancer of the breast. During the skin preparation preliminary to operation, no method of preparing the skin should be used which allows rubbing the skin over the tumor. This could be very damaging by producing venous emboli.

Of more importance, perhaps, than the precautions in technics listed above would be the destruction of the disseminated cells. It occurred to Cole and associates (70, 71) that these cells might be destroyed by some of the anticancer agents now in use, although they will not kill cells which are entrenched in a metastasis having an established blood supply. This group of workers designed an experiment utilizing Walker 256 carcinosarcoma cells. They inoculated the cells into a branch of the portal vein of rats to stimulate venous emboli to the liver in a human being, and then gave 0.5 mg. per kilogram of nitrogen mustard into the same vein one minute later. The same dosage was carried out in another series of rats, giving the nitrogen mustard into the peritoneal cavity one hour after inoculation; and in another, giving the nitrogen mustard into a systemic vein one hour after inoculation of the cells. These investigators found that, when nitrogen mustard was given at the time of the inoculation or within an hour afterwards, the nitrogen mustard was quite effective in decreasing the percentage of "takes"; for example, "takes" were reduced from 91.7 per cent in controls to 17.8 per cent in the treated animals when the nitrogen mustard was given one minute later into the same vein. When nitrogen mustard was given into the peritoneal cavity one hour after inoculation of cells, the percentage of "takes" in the controls was 86.7 per cent and in the treated animals was 41.3 per cent. Thio–

the entire group. All surgeons will agree that if a biopsy of the breast or thyroid is performed, the resection of the cancer should be carried out immediately after the frozen section report of cancer, if at all possible. The 95 cases reported by Davis as having operation 24 or more hours after biopsy had their biopsy in hospitals elsewhere and were sent to Illinois Research Hospital for operative care. Also, all surgeons agree that when a biopsy is performed, gloves, instruments, and drapes must be changed before the resection is begun, lest the surgeon implant cells into the massive wound created during the resection.

PRINCIPLES IN TREATMENT

In spite of an enormous amount of work being done on numerous methods of therapy, surgical excision and radiation remain the only curative procedures for cancer. Many agents are palliative, some prolong life and others do not.

Surgical Resection. Gradual progress has been made during the past few decades in the operative treatment of malignant disease. The development of refinements in anesthesia and the proper use of blood have made radical operation for cancer possible with a comparatively low mortality rate. The extent of operation has been increased but cannot be increased much more because of anatomic limitations. Super radical procedures—such as excision of the rectum, bladder, prostate, or uterus at one stage—are being performed for advanced tumors, but the five-year survival rate from these procedures is low whereas the mortality rate is high. The surgical profession is at present evaluating the benefits, operation mortality, disability, and so forth, trying to arrive at standards which would clarify the indications and contraindications of these massive operations for advanced cancer.

It must be emphasized that operations for cancer are distinctly different from operations for benign lesions. The primary difference lies in the fact that in cancer operations the surgeon must remove all tissue, if possible, which may possibly harbor cancer cells. Accordingly, he must be trained in the finer technics of surgery, allowing him to perform massive operations without damaging vital structures and without jeopardizing the patient's life from the standpoint of the patient's physical reserve.

The majority of patients with cancer have one or more serious decrements in physical reserve by the time they come to the surgeon for operation. One of the most common and most important is malnutrition, which is very frequent in oral and gastrointestinal cancer because of inadequate intake resulting from pain (when eating, in oral cancer) and digestive disturbances (in gastrointestinal cancer).

For reasons enumerated above, meticulous preoperative preparation must be carried out in many patients with cancer. Preoperative examination should routinely include blood protein and N.P.N. determinations, in addition to routine blood and urine examinations. There are two primary motives for these precautions: 1. to obtain indications for treatment and improvement of operability; and 2. to plan the operation in case certain decrements cannot be corrected. One of the most common errors made today by capable surgeons is to proceed with a conventional type of operation when the patient's physical reserve will not actually tolerate it. In other words, we must not perform a given operation on a patient if we have good reason to think he will not survive it. True enough, the patient often dies when we thought he would survive. This is not an excuse for our error but should serve to stimulate us to assay our patients operability more closely; we hope the day will come when we can say with certainty that a certain patient will survive a certain operation and not another. We must be prepared to alter the type and extent of our operation (perhaps in stages) if it will save the patient's life.

Radiation. There are numerous types of radiation, most of which induce changes in the nucleus of the cell which interfere with mitosis. Primary radiations used clinically include x-rays, gamma rays, electrons, beta rays, neutrons, and protons (68). The secondary radiations projected into the tissues consist of protons and electrons. Of the numerous machines or agents being utilized in the treatment of cancer the following should be mentioned: 1. x-ray; 2. radium; 3. beta-

TABLE 3. Specific Agents Used in Cancer Chemotherapy

(Modified from Karnofsky in CA—Bulletin of Cancer Progress, 5:170, 1955)

Agents	Principal Route of Administration	Usual Dose	Acute Toxic Signs	Major Late Toxic Manifestations
		Polyfunctional Alkylating Agents		
Methyl-bis(β-chloroethyl)amine HCl (HN_2) (Mustargen)	I.V.	0.4 mg./Kg. single or divided doses	N.&V.*	Therapeutic doses moderately depress peripheral bloodcell count; excessive doses cause severe bone-marrow depression with leukopenia, thrombocytopenia, and bleeding. Maximum toxicity may occur two or three *weeks after last dose. Dosage,* therefore, must be carefully controlled.
Triethylenemelamine (TEM)	I.V. Oral	0.04 mg./Kg ×3 20–40 mg. in 1 mo.	Occasional N.&V.*	
Triethylenethiophosphoramide (Thio-TEPA)	Oral I.V.	5–10 mg./day 0.2 mg./Kg ×5	None	
1,4-Dimethanesulfonyloxybutane (GT-41) (Myleran)	Oral	2–8 mg./day 150–250 mg./course	None	
		Antimetabolites		
4-Amino-N[10] methylpteroylglutamic acid (Amethopterin)	Oral	2.5–5.0 mg./day	None	Oral and digestive-tract ulcerations; bone-marrow depression with leukopenia, thrombocytopenia, and bleeding.
4-Aminopteroylglutamic acid (Aminopterin)	Oral	0.25–1.0 mg./day	None	
6-Mercaptopurine (6-MP) (Purinethol)	Oral	2.5 mg./Kg./day	None	Therapeutic doses usually well tolerated; excessive doses cause bone-marrow depression.
		Steroid Hormones and Related Substances		
Androgen				
Testosterone propionate	I.M.	50–100 mg. 3× weekly	None	Fluid retention, masculinization.
Methyltestosterone	Oral	100 mg. daily	None	Fluid retention, masculinization.
Estrogen				
Diethylstilbestrol	Oral	1–5 mg. 3×daily	Occasional N.&V.*	Fluid retention, feminization, uterine bleeding.
Ethinyl estradiol	Oral	0.1–1.0 mg. 3× daily		
Adrenal Cortical Hormones				
Cortisone acetate	Oral	50–300 mg. daily	None	
Hydrocortisone acetate	Oral	50–200 mg. daily	None	Fluid retention, hypertension, diabetes, increased susceptibility to infection.
Meticorten	Oral	20–100 mg. daily	None	

TEPA has the same, and perhaps more, effect than nitrogen mustard when used in this prophylactic or adjuvant way. As soon as it was discovered that the nitrogen mustard was effective in a prophylactic way in animals, Cole and associates began (March, 1956) its use in human beings. As yet, it is too early to draw any conclusions from the procedure.

Chemotherapy. For many decades, efforts have been made to treat cancer with anticancer agents, but the early agents were not very effective. Perhaps the first one which offered promise was Coley's bacterial toxin, initiated about 1893. A few very beneficial effects were observed, but in the majority of cases no benefit was noted.

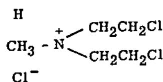
Nitrogen mustard, the first promising chemical agent introduced, was found by Goodman, Gilman, and associates (38) to be effective experimentally as well as clinically, although no clinical cures could be obtained. Nitrogen mustard produces its effect by substituting alkyl groups for hydrogen. The most likely site for this substitution process is in the nucleoproteins of the cell nucleus. It produces chromosome damage with inhibition of mitosis similar to x-rays. It inhibits a large number of intracellular enzymes. In 1948, Farber (72) found that the 4-amino analogues of folic acid would produce regression of acute leukemia in children. Of thousands of drugs tested for anticancer effect, several hundred show beneficial effect in animals. The number showing beneficial effect in human beings is much smaller (Fig. 7). The more important ones being used in human beings at the present time are illustrated in Table 3.

The use and results of various chemical agents in the treatment of cancer have been discussed by Sykes and associates (73). Although many of these agents will cause regression in many patients with cancer, none of those available at the present time will cure cancer. Nitrogen mustard is quite effective in Hodgkin's disease and less so in other types of lymphomas. It will often cause regression in carcinoma of the lung (74). Triethylenemelamine is often effective in Hodgkin's disease, other types of lymphomas, and leukemia. Thio–TEPA will often produce prolonged remissions in chronic leukemias (73); likewise, it is often effective in carcinoma of the breast and ovary (75). Details of the more recent use of chloramubucil and other alkylating agents may be found in the Proceedings of the Alkylating Conference (76) held in 1957.

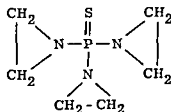
The importance of nucleic acid anabolism in chemotherapy has been emphasized by Rhoads (77). He calls attention to the fact that nucleic acid is a vital part of all cells and that cancer cells contain more nucleic acid than normal cells. Nitrogen mustard, which is one of the more effective chemical agents in the destruction of cancer, exerts a very destructive effect on nucleic acid, even in a high dilution. Also it is known (Herriott, 1951) that ionized radiation, the best physical agent available for the treatment of cancer, depolymerizes nucleic acid. Furthermore, chromosome abnormalities have been described in cancer cells, and nucleic acid is known to be a very important constituent of the chromosome.

ALKYLATING AGENTS

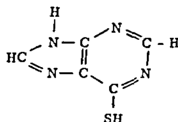
ANTIMETABOLITE



Nitrogen Mustard



Thio-TEPA



6-Mercaptopurine

Fig. 7. Three examples of anticancer agents used in the treatment of human cancer.

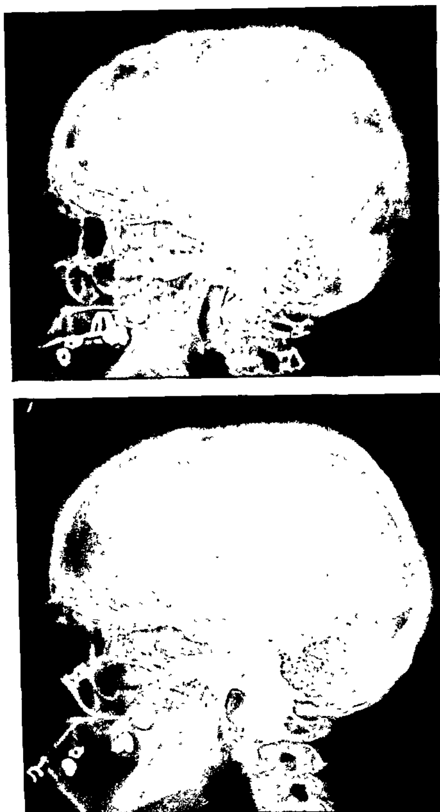


Fig. 8. Osteolytic lesions of the skull (due to metastases from a carcinoma of the breast) obliterated by bilateral adrenalectomy and oophorectomy. Above, the skull reveals innumerable destructive lesions. Below, eighteen months after bilateral adrenalectomy and oophorectomy all the lesions have disappeared. However, permanent remission is not expected.

Adrenocorticotropic Hormone (ACTH)	I.V. or I.M.	25–50 mg. by continuous infusion (10–20 mg. every 3 hr.)		
		Radioactive Isotopes		
Iodine (I^{131})	Oral, I.V.	100–200 mc.	None	Myxedema, bone-marrow depression, renal damage.
Phosphorus (P^{32})	Oral, I.V.	3–7 mc.	None	Bone-marrow depression.
Gold (Au^{198})	Intrapleur.	75 mc.	None	Bone-marrow depression.
	Intraabd.	75 mc.	None	Bone-marrow depression.
		Miscellaneous Drugs		
Urethane	Oral	2–4 gm. daily	N.&V.*	Bone-marrow depression.

* N.&V. = Nausea and vomiting

Hormone Therapy. The use of hormones in anticancer therapy constitutes "chemotherapy," but treatment with these substances is discussed separately since they are vitally different than the chemicals described above.

It has been known for decades that castration is occasionally very beneficial in cancer of the prostate and cancer of the ovary. The work of Huggins early in the 1940's advanced this knowledge appreciably. Huggins has shown that castration is definitely effective in producing regression of certain tumors (prostate and breast), and that administration of estrogen to male patients with carcinoma of the prostate results in pituitary inhibition with testicular atrophy, thus equivalent to castration. Huggins and associates (78, 79) likewise have demonstrated that bilateral adrenalectomy produces regression in certain tumors (particularly carcinoma of the breast) and may relieve symptoms for several months, although no patients have been cured by this procedure (Fig. 8). Hypophysectomy (80, 81) is also effective in producing regression of certain tumors, particularly carcinoma of the breast. Adrenal steroids have an inhibitory effect on certain tumors, primarily those involving the lymphatic tissue (e.g., leukemia).

Use of Viruses as an Anticancer Agent. The use of these agents in the treatment of cancer is more recent than of those mentioned above. Actually, not enough data have been accumulated to indicate how effective they might be. However, of the numerous viruses tried experimentally, 11 have been effective in inhibiting the growth of one or more tumors (3). Among these agents, the Russian encephalitis virus, the Bunyamera virus, and the Egyptian 101 virus seem to offer the most promise.

RESULTS

As has been stated previously, surgery and radiation are the only forms of therapy which result in cure of cancer. The various forms of chemotherapeutic agents, including the alkylating agents and hormones, will often cause a regression of the tumor for a few months or longer, but no cures have been reported; on many occasions, life has been distinctly prolonged (Table 4). Particularly is this true in leukemia which is treated by alkylating agents and antimetabolites, often alternating, because the disease tends to become resistant to one agent after a few weeks.

Summaries of reports presented at the Third National Cancer Conference in 1957 indicate that progress is being made in the cure or five-year survival rate. For example, Hammond (82), who analyzed the entire data presented for malignant tumors (exclusive of carcinoma of the skin, the most favorable of all) in various regions of the body, reports that several years ago we were saving one out of four persons who contracted the disease, whereas now we are saving one out

TABLE 5. Resectability Rate, Five-Year Survival Rate, and Operative Mortality Rate (Expressed in Percentages) After Resection for Tumors in Various Regions of the Body

(These figures combine charity and private cases. The operability and five-year survival rates are lower in the former, and the operative mortality rate higher; the reverse is true for private cases.)

	Resectability*	Five-Year Survival Rate of Resectable (Favorable Cases)	Mortality Rate for Resected Cases
	%	%	%
Bladder	65	60	5
Breast—total	80	50	0–0 5
without axillary met.		75	
with axillary met.		35	
Cervix Uteri	40	30–45	1–3
Colon	80	55	3
Corpus Uteri	90	65	0.5
Esophagus†	30	5	15
Gallbladder	10	5	10‡
Bile Ducts	30	10	3
Kidney	75	50	4
Larynx	85	50	4
Lung	30	25	7
Melanoma	70	40	1–3
Ovary	50	35	0–1
Pancreas	25	1–3	20
Prostate	15	45	3
Rectum	80	50	3
Skin	95	95	0
Stomach	25	25	6§
Tongue	70	30	5–10

* Meaning no residual tumor after resection.
† Excluding extension of gastric Ca into esophagus.
‡ Including partial resection of right lobe of liver.
§ About 10 per cent for total gastrectomy.

process, either host resistance or virulence of the cell, changes (usually fairly rapidly) and microscopic nests which have been lying dormant flare up and begin to grow.

Unfortunately tumors in many areas grow very rapidly and are not curable at the time of operation, although they may be resectable. Carcinoma of the stomach, esophagus, and pancreas are examples. Also, no more than 25 per cent of the patients with carcinoma of the esophagus and pancreas are resectable, without residual tumor, by the time the patient is operated on.

In Table 5 we have listed the tumors commonly treated by operation and have indicated their rate of resectability, percentage of five-year survival, and the operative mortality rate. The figures represent estimates or an average derived from a large number of articles in the medical literature (83–104).

Again, we emphasize that the technic for operation for cancer must be different from other operations. Resection must be wide, removing as much adjacent nonvital tissue as possible and excising all involved resectable lymph nodes. The necessity of lymph node resection is exemplified by the publication by Meyer and Gumport (103) dealing with malignant melanoma. They reported a five-year survival rate of 41.5 per cent in 65 cases. Of these, 40 had regional node dissection along with removal of the primary, with a five-year survival rate of 52.5 per cent. The survival rate was 33.4 per cent for the patients having positive nodes and 66.7 per cent in those having negative nodes. This wide difference between the five-year survival rate of patients with and without positive nodes exists in almost every tumor treated by operation, i.e., the results are almost twice as good in patients having negative nodes as it is in patients having positive nodes.

TABLE 4. Neoplastic Diseases Responding to Chemotherapy

(Modified from Karnofsky in CA—A Bulletin of Cancer Progress, 5:171, 1955)

DIAGNOSIS	USEFUL AGENTS	RESULTS
Acute Leukemia Children	Amethopterin, 6-MP, 6-MP +Azaserine, Adrenocortical hormones	70% bone-marrow improvement; 50% of patients live one year or longer
Adults	Adrenocortical hormones, 6-MP, Amethopterin	15–25% improved for several months or longer
Chronic Myelocytic Leukemia	Myleran, TEM, HN_2, 6-MP, P^{32}	Patients maintained in good condition during major portion of disease; life occasionally prolonged
Chronic Lymphatic Leukemia	TEM, P^{32}, Adrenocortical hormones	Patients maintained in good condition during major portion of disease; life occasionally prolonged
Hodgkin's Disease	HN_2, TEM	Occasional favorable response, but no definite prolongation of life
Lymphosarcoma	HN_2, TEM	Occasional favorable response, but no definite prolongation of life
Multiple Myeloma	P^{32}, I^{131}, Adrenocortical hormones, Urethane	Symptomatic relief in about 50% of cases, and objective hematological improvement in 15%
Polycythemia Vera	P^{32}, TEM, HN_2	Prolonged clinical remissions, particularly with P^{32}
Carcinoma of Lung	HN_2, TEM, Au^{198}	Brief improvement in about 50% of cases
Carcinoma of Ovary	TEM, HN_2, Au^{198}, Thio-TEPA	30–50% of cases improved for 1 to 3 months, sometimes longer
Carcinoma of Thyroid	I^{131}	Frequent marked improvement in properly selected cases
Carcinoma of Breast	Estrogens, Androgens, Thio-TEPA, Au^{198}, TEM, HN_2	20–50% improved by hormonal therapy; life may be prolonged in some cases
Carcinoma of Prostate	Estrogens, Au^{198}	80% of cases respond to hormonal therapy; definite prolongation of life
Miscellaneous Carcinomas and Sarcomas	HN_2, TEM, Thio-TEPA, Au^{198}	In rare instances, favorable responses occur

of three. These figures indicated, however, that very little progress has been made in carcinoma of the stomach, lung, esophagus, ovary, and pancreas. Perhaps the most improvement has been made in carcinoma of the cervix.

In a discussion of results, it must be made clear that the five-year survival rate, which is commonly used as the standard for results, means survival and not cure. It must be admitted that more than just a few patients who are entirely well at the end of five years will develop metastases months to years later and die of their cancer. This indicates that some

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22

FRACTURES, DISLOCATIONS, AND SPRAINS: GENERAL CONSIDERATIONS

R. Kirklin Ashley and LeRoy C. Abbott*

GENERAL CONSIDERATIONS

Fractures, dislocations, and sprains involve the musculoskeletal system. Occasionally other contiguous structures—such as the viscera, the central nervous system, and, at times, the special sensory organs—are implicated. Because bone, tendon, and muscle are specialized structures, particularly in the manner in which they heal, careful consideration must be given to the diagnosis and management of conditions involving them. In many instances, the function regained following injury to these structures will depend largely upon the judgment, skill, and attention to detail of the attending surgeon. Frequently, impaired function is quite obvious, not only to the patient but to the layman as well.

FRACTURES

Definition. A fracture is a break or interruption in the continuity of bone or cartilage.

Classification (1). Based on the Number of Fragments. When a bone is broken into two parts, it is generally referred to as a *complete* fracture, provided the bone is completely divided; or an *incomplete* fracture, if the bone is not entirely divided. If the bone is fractured into *more than* two fragments, it is then referred to as a *comminuted* fracture. A *greenstick* fracture is an incomplete fracture commonly seen in childhood.

Based on Integumental Covering. *Closed* fractures are those in which there is no communication between the fracture site and the external environment. *Open* fractures are those in which there is such communication. Ordinarily, an open fracture is considered to be one in which the skin is broken and the bone protrudes, or at some time has protruded, through the skin. However, it must be borne in mind that a fracture of the mandible which enters a tooth socket is also an open fracture, even though it is the mucous membrane rather than the skin through which communication with the external environment occurs. In the older terminology, the word "compound" was used instead of the now accepted term *open*, and the word "simple" instead of *closed*.

Based on the Appearance of the Fracture. Transverse fractures occur when the fracture line is at right angles to the longitudinal axis of the bone. *Longitudinal* fractures (less common) follow the long axis of the bone and are a splitting type of injury, as seen when a piece of kindling is split. A *spiral* fracture twists around the bone as it proceeds along the longitudinal axis, as the name spiral implies. An *oblique* fracture occurs obliquely to the longitudinal axis of the bone (Fig. 1).

Based on the Mechanism of Injury. In *direct force* fractures (Fig. 2), that portion of the bone to which the force is applied is the site of the fracture. An *indirect force fracture*

* We gratefully acknowledge the help and careful attention to editorial detail given by Eleanor Little, Editor, Department of Orthopaedic Surgery, University of California School of Medicine.

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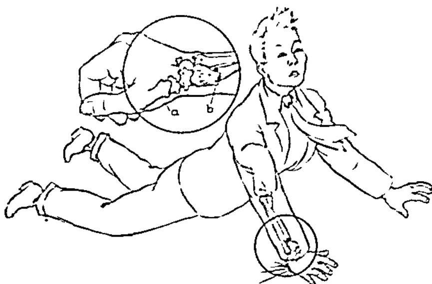


Fig. 3. A Colles' fracture. Note the patient falls with impact at point a; fracture occurs more proximally at point b.

taneously as, for instance, in the area of a metastatic tumor. In such instances the term *pathologic fracture* is applied (Fig. 4). Pathologic fractures can also occur in many other diseases of the bone—such as Paget's disease—in hyperparathyroidism, as a result of impaired nerve supply, in tabes dorsalis, in syringomyelia, in transverse myelitis, and in spina bifida.

Based on Eponym. Fractures may be classified according to the illustrious surgeon who first described that particular fracture under discussion, and in such instances the eponym is applied. Learning the various types of fracture then, becomes a matter of rote and memory: Colles' fracture, a fracture of the radius near the wrist; Pott's fracture, a special type of fracture about the ankle; Malgaigne's fracture, a special fracture involving the pelvic girdle. It is beyond the scope of this chapter to discuss these particular fractures in any detail.

Etiology. There are many factors which contribute to the etiology of fractures. The most common of these is trauma. Contributory factors are *sex*, fractures being more frequent in men probably due to greater vocational hazards. *Age* is also a contributory factor, most fractures occurring in about the third decade when persons are younger, more active, more continuously exposed to occupa-



Fig. 4. X-ray showing fracture through a simple bone cyst occurring in midshaft of the femur in a boy aged 10 years. The fracture occurred when the patient turned over in bed.

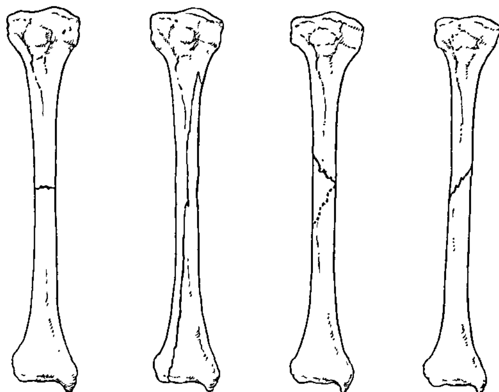


Fig. 1. The common types of fracture designated according to the appearance of the fracture line.



Fig. 2. Common type of direct force injury resulting in isolated fracture of the ulna precisely at the point of impact.

(Fig. 3) is one in which the fracture site will occur at some point distant to the application of the force. In *avulsion fractures*, interrupted bony continuity results following muscle or ligamentous pull at the site of either their origin or insertion.

It is impossible to emphasize adequately enough the importance of understanding the *mechanism of injury* since, in many instances, it is the key to reduction by manipulation.

Based on Location. According to the anatomic location of the fracture site on the bone, certain classifications may be made; for instance, a fracture of the shaft, the condyle, the tuberosity.

In the growing bones of childhood, special terms are used: i.e., a fracture of the shaft of a long bone is referred to as a fracture of the diaphysis. A fracture of the diaphyseal side of the epiphyseal plate is referred to as a metaphyseal fracture. A fracture through the epiphysis is called an epiphyseal fracture.

Based on the Status of the Bone Structure Prior to Fracture. The majority of fractures are traumatic. Not infrequently, however, a fracture may occur spon-

union, the bone is gradually strengthened and the callus resorbed. If satisfactory position of the bone has been obtained and restoration has been normal, it is often difficult later to determine the exact site of the fracture, especially in children. Remodeling takes place as a result of the stress and strain of use and muscle pull, and the final shape of the bone will depend upon the internal and external stresses applied. The time required for each stage of the healing process is governed by many variables. For a more detailed description of fracture healing, the reader is referred to the excellent section on the healing of fractures in A. W. Hamm's *Histology* (3).

Diagnosis. HISTORY. A careful and detailed history should be obtained from the patient or, in cases where the patient is in no condition to give such a history, by those who accompany him. Particular and careful effort should be made to learn the precise mechanism of injury. Many times it is the first impulse of the patient to say that the injury occurred with such speed that it is impossible for him to recall exactly what mechanism was involved. Unless intoxicated or unconscious as a result of the injury, however, most patients on careful questioning are able to give a fairly accurate description of this mechanism, despite their first statement that they fail to remember it. They will then describe it as a direct force, a twist, a fall backward or forward, to the right or to the left side. It is not uncommon to elicit a history of deep, aching pain which has continued for a period of several weeks or months prior to the time of fracture in cases of pathologic fracture.

Point Tenderness. Point tenderness is invariably noted in fractures and is exactly what the name implies. The injured area is gently palpated with the finger or examined with the blunt point of a pencil. At one point, the examiner will encounter exquisite tenderness. That point is the exact fracture site.

Deformity. There is obvious deformity in fractures where there has been considerable disarrangement of the part. Many times there is marked soft tissue swelling which obliterates deformities of less magnitude. By very gentle palpation, even small amounts of deformity can be noted. It is extremely important that most careful and gentle palpation be employed because of the severe amount of pain which can be brought about by heavy-handedness on the part of the examiner. This pain is of such an intense and deep-seated nature that it can produce marked shock.

Crepitus. Crepitus is a grating which can be heard or felt when the rough, bony fragments rub against each other. It is often not elicited when there is interposition of soft parts. It may be simulated by such other conditions as movement of a roughened joint surface adjacent to the fracture, subcutaneous emphysema, or tenosynovitis.

Abnormal Mobility. The presence of abnormal mobility is pathognomonic of fracture. In fractures which occur near a joint, however, it is necessary to distinguish abnormal mobility at the fracture site from the normal mobility of a given joint.

Pseudoparalysis. This is a term which is given to the loss of function which may accompany fractures. It is seen most classically in children. It is due to loss of mechanical support and of mechanical advantage of muscles, plus marked pain on attempted motion. Unfortunately it is not a reliable physical finding, since it may also accompany contusions, sprains, and other injuries. It may sometimes be hysterical in nature.

Auscultation and Percussion. Occasionally, when one is unable to elicit crepitus by gentle palpation, it can be heard with the use of a stethoscope applied locally. If there is loss of contact of the bone end, auscultation can be a valuable adjunct in diagnosis. For example, the stethoscope is placed on the symphysis pubis. The patella is then tapped with the finger, and an osteal ring is heard. If, however, the opposite patella is tapped and there is a fracture of the hip with loss of contact, or poor contact, an osteal ring will not be heard. Instead there will be a muffled sound, which is readily distinguishable from the ringing sound characteristic of the normal uninjured side.

Local Swelling. Following fracture, the *immediate* swelling is due to hemorrhage. Further swelling usually occurs later. This is the result of inflammatory exudate and impaired drainage of blood, lymph, and extracellular fluid.

Nerve and Blood Supply. Particularly careful evaluation of the nerve and blood supply to the distal portion of a fractured

tional hazard, engaged in athletics, and, in general, less cautious. However, it is well known that fractures may occur in intrauterine life—during the passage down the birth canal or in the course of delivery—or at any other time during life from infancy to far-advanced years. *Pathologic conditions of bone*, as has already been mentioned, may so weaken it as to be considered an etiologic factor.

Pathology and the Repair of Fractures (2). In the normal bone, healing begins immediately following fracture. Under auspicious conditions, the fracture progresses through five stages until consolidation of the bone occurs (Fig. 5). These stages are: 1. hematoma; 2. granuloma; 3. callus; 4. consolidation; 5. remodeling.

1. *Stage of Hematoma.* When fracture first occurs, blood oozes through lacerated vessels and a hematoma is formed, which bathes the fractured bone ends and brings about a continuity by means of the pool of blood. The periosteum and muscles, which are often torn from the bone ends to a variable extent, surround the hematoma.

2. *Stage of Granuloma.* The hematoma now undergoes organization. The organized hematoma is invaded by a network of capillaries which grow into it from the surrounding tissues. The organized hematoma containing a capillary network is, at first, a friable type of granulation tissue, which gradually becomes firmer and forms an elastic union between the bone surfaces.

3. *Stage of Callus.* The repair site is now entered by osteoblasts, and callus ensues. Callus lacks the typical lamellar structure characteristic of mature bone and has been termed "woven bone." Clinical examination at this stage will reveal a growing firmness at the fracture site. When the mineral salts are deposited through the action of the enzyme alkaline phosphatase, the fluffy white shadow characteristic of a healing fracture is visible by x-ray.

4. *Stage of Consolidation.* With the passage of time this callus, or woven bone, is transformed by osteoblastic activity and results in typical mature bone with characteristic lamellar structure.

5. *Stage of Remodeling.* The last stage, remodeling, is exemplified by the formation of a rounded excrescence on the outer surface of the healing bone. This not only forms a collarlike protuberance which surrounds the bone but also obliterates the medullary canal within. Where the periosteum has been stripped to a considerable degree and the fracture hematoma is large, with marked displacement of fragments, the size of the excrescence will be proportionately large. With a lesser degree of derangement from the norm, the excrescence may be smaller; the size varies from case to case. In children, there is usually abundant callus. Following

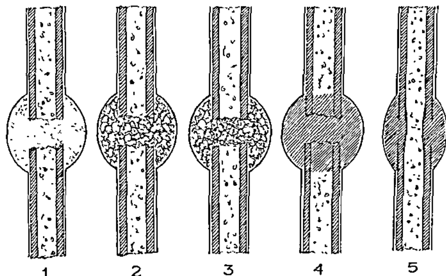


Fig. 5. Schematic drawing of the five stages of regeneration of the bone. 1, Hematoma; 2, granulation; 3, callus; 4, consolidation; 5, remodeling. (From Adams, J. C. Outline of Fractures, E. & S. Livingstone, Ltd.)

X-ray studies must include an anteroposterior view, as well as a lateral view (4) (Fig. 6). Occasionally, additional views will be necessary in certain types of fractures, particularly in those fractures which occur around or near the joints and are apt to have involved the articular surface of a joint. In no case, however, is one view ever sufficient.

Furthermore, because of the presence of epiphyseal plates of irregular outline in childhood, there is occasional confusion with the presence or absence of a fracture line. Therefore in children, x-rays of the *opposite, uninjured member for comparison* with the injured side must be taken. In certain instances, x-ray studies must be repeated after an appropriate time interval, perhaps of two or three weeks, in order to clarify the presence or absence of fracture. Particularly is this true of linear, undisplaced fractures which involve the small bones of the wrist, the ribs, and sometimes the neck of the femur. This is also strikingly seen in fatigue fractures (march fracture) of the metatarsals. An x-ray taken shortly after the injury may appear to be normal. Two to three weeks later, however, a repeat study may demonstrate some healing reaction or an obvious fracture line where none was evident before (Fig. 7). The fracture line will appear in the later study because of the hyperemia and resultant demineralization at the fracture site, which was not evident at the time of the original study. During the period between the two x-ray studies, the condition should be treated as though it were a fracture.





Fig. 7. Showing importance of second x-ray taken subsequently when diagnosis is in doubt. Above, normal x-ray of foot (patient complaining of pain in metatarsal); left, film of same foot two weeks later showing callus formation about a typical "march fracture" of the third metatarsal neck.

In the clinical differential diagnosis between a fracture and a dislocation, in instances of *fracture* there is *abnormal mobility,* where there should be *no mobility.* In

extremity must be made because of the serious consequences which may result from the impairment of these two vital functions. Any impairment of these structures should be carefully noted prior to reduction. Thus it will be ascertained that residual vascular or neurological deficit has been the result of the injury itself.

Systemic Reaction. Following fracture, a slight fever of one or two degrees will often be noted. During the first 24 hours there may also be a polymorphonuclear leukocytosis. These conditions are especially marked in childhood.

There is no substitute for a careful history and physical examination of the whole patient if an accurate diagnosis is to be made. These two steps—history and physical examination—are equally as important in the management of traumatic injuries as they are in all other phases of clinical medicine and surgery. Following careful clinical examination, radiologic examination of the injured member is mandatory. Prior to sending the patient for radiologic examination, immobilization of the fractured part should also be routine. This is of the utmost importance, and will be discussed later under "Treatment."

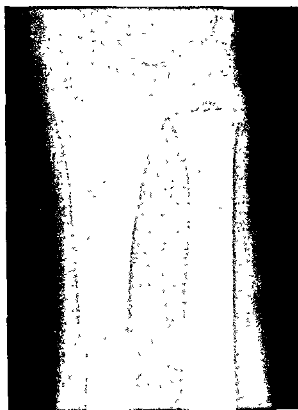


Fig. 6. Showing importance of obtaining anteroposterior and lateral views. Left, anteroposterior film showing acceptable alignment; below, lateral view showing marked and unacceptable angulation.



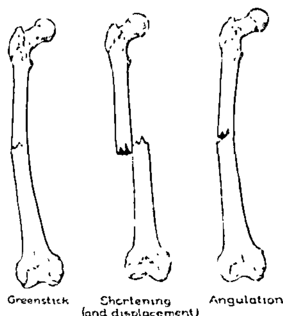


Fig. 8. Types of deformity seen in fractures.

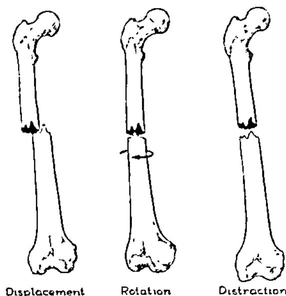


Fig. 9. Types of deformity seen in fractures.

following the injury (8). This will not delay union or impair functional results. If this procedure of so-called "delayed-reduction" is carried out, the extremity must be supported in a plaster of Paris splint during the interim. Two factors which may advise delayed reduction are: 1. critical condition of the patient; and 2. excessive swelling of the injured member. Contraindications to delayed reduction are the presence of nerve injury, vascular injury, dislocations, and open fractures.

METHOD OF REDUCTION. *Closed Reduction.* The ideal method of reduction is that of closed manipulation of the fracture, provided accurate reduction and satisfactory maintenance of reduction can be obtained by this technic (9). In order to obtain an accurate reduction, a careful analysis of the deformity first must be made. Various deformities which may occur are: shortening, displacement, angulation, rotation, and distraction (Figs. 8, 9). Frequently they exist in combination. When reduction by manipulation is performed, correction of each of the existing deformities should be carried out in an orderly fashion. It is here that large dividends are paid by having a thorough understanding of the mechanism of injury and by having analyzed carefully the various deformities prior to the time of reduction. For each deformity a force must be applied in the direction *opposite* to it in order to obtain accurate and orderly reduction. If there is shortening, traction is its correcting or reducing force. Constant, steady, nonvibrating traction prior to manipulation may aid in securing reduction, by diminishing muscle spasm and shortening. If there is displacement laterally, then force medialward is the reducing force. In the same fashion, angulation, rotation, and distraction deformities may be corrected.

Open Reduction. Open reduction is utilized when the closed method fails to give reduction or fails to provide adequate stability, necessitating the use of internal fixation. It should be used only by individuals who have been carefully trained in its intricacies and who are thoroughly familiar with its management and possible complications (10). Open reduction and internal fixation are also used in the presence of certain pathologic conditions of bone which preclude the use of prolonged bed rest. This is seen, for example, in the elderly patient who has Paget's disease as well as a fractured femur. The use of open reduction and an intramedullary rod is justifiable in such patients, even though adequate reduction and fixation might have been obtained by the closed method. Prolonged bed rest in such a patient frequently results in mobilization of large amounts of calcium from the diseased skele-

cases of *dislocation* there is *restriction in mobility,* where there should be *free mobility.* Here again, x-ray diagnosis is of prime importance and is necessary in order to protect the patient and to serve as a record in the event of future litigation.

Because this chapter is devoted to a discussion of fractures, dislocations, and sprains, the reader's attention is more specifically directed to a local area of injury. However, nothing can be more dangerous than to limit attention to the "local area." The entire patient should be examined. The examiner should be constantly on the alert to the possibility of the presence of multiple fractures and injury to the adjacent structures, the treatment of which may take precedence over that of the bone (5). For example, in fracture of the pubic portion of the pelvis, injury to the bladder or membranous portion of the urethra is of far greater immediate consequence than is the interruption of the continuity of the bone. In like manner, fractures of several ribs may lead to serious consequences and jeopardize the life of the patient if the underlying lung parenchyma and blood vessels have been severely lacerated.

Treatment. SYSTEMIC. Fracture is often accompanied by shock, and immediate attention must be given to the amelioration of this condition. Details of the treatment of shock will be found elsewhere in this text. The principles of the treatment of shock are followed in the usual fashion. In addition, it must be remembered that fractures, particularly of the large bones or when multiple, are usually accompanied by hemorrhage which may amount to from 1,000 to 1,500 ml. or more of blood. In a closed fracture, this hemorrhage occurs into the soft tissues, and, though it is not lost from the body, it is lost from the effective circulating blood volume and should be replaced by transfusion as quickly as possible.

LOCAL. Immediate immobilization of the injured part can prevent further injury and also help to control shock (6). There are many forms of immobilization, the simplest perhaps being the plaster of Paris cast which has the advantages of being readily available and made to order for the patient, thus providing a perfect fit. There are, in addition, padded cardboard splints, metal splints, pillow splints, and the opposite extremity, in the case of a leg, which offers a good splint.

In order to secure satisfactory union of the fracture, certain fundamental criteria must be met. They are *bone contact, adequate immobilization, good blood supply,* and *absence of infection.* Of these fundamental criteria three—bone contact, immobilization, and absence of infection—can be controlled and modified by the physician. The fourth, good blood supply, is in most instances beyond the control of the physician. There are certain fracture sites that have been recognized as having poor blood supply, for example, the junction of the middle and distal thirds of the tibia and the shaft of the ulna. It is important to have some knowledge of these poorly vascularized areas, since the time required for union to occur at these sites is usually quite prolonged. When union is slow to occur, the surgeon, being conversant with the situation, will persist in conservative measures rather than resort to the more radical ones, which may not better blood supply and therefore not attack the basic problem (7). Assuming that the four fundamental requirements have been met, union can practically be assured. However, union does not, of itself, imply an entirely satisfactory result. The union must occur with the bones in a satisfactory position, and the joints must be freely mobile; muscle power too must be regained in order to consider the result perfect. Therefore, the treatment of a fracture includes the classical "three R's"—Reduction, Retention (or immobilization), and Rehabilitation.

Reduction. Accurate reduction of a fracture, or "setting the bone," is necessary in most fractures which show any degree of deformity. There are, however, certain exceptions, as will be discussed in later chapters. To obtain satisfactory reduction in most cases a general anesthetic, regional anesthetic, spinal anesthetic, or some similar form of anesthesia is required. This is necessary if adequate muscle relaxation is to be obtained so that successful manipulation can be accomplished.

TIME OF REDUCTION. Under ideal conditions, the best time to reduce a fracture is as soon as possible following the diagnosis. It has been shown that a fracture may be reduced at any time during the first 14 days



Fig. 11. Anteroposterior and lateral views showing internal fixation of comminuted spiral fracture at junction of middle and distal third of tibia by means of two screws. Additional plaster immobilization is necessary.

When the extremity is released from the cast or other fixation appliance, increased efforts must be directed toward mobilizing the previously immobilized joints and strengthening the weakened muscles. There is no substitute for active exercise in accomplishing these two important steps. Massage, warm compresses, and soaks are many times comforting and of psychologic benefit, but they will never strengthen a muscle nor mobilize a joint. Here again, special exercises must be prescribed by the surgeon. He should be sure that the patient understands what is required of him, by having the patient perform his exercises on several subsequent visits. The physical therapist can be of great value, but it is the direct responsibility of the surgeon to prescribe exercises and other forms of treatment to be given by the therapist, and also to see that these are carried out meticulously. Rehabilitation plays an integral part in the treatment of traumatic injuries, and it is the duty of the attending surgeon to make use of all of its facilities in his effort to return the patient to the highest functional level (4).

Special Treatment of Open Fractures. Because of the communication with the external environment at the fracture site, infection may occur in the case of open fractures. Infection may impede or mitigate against union. Therefore, special attempts to avoid such complications must be made in the case of open fractures. If the fracture is seen within six hours of the time of injury, immediate débridement of the wound in the operating

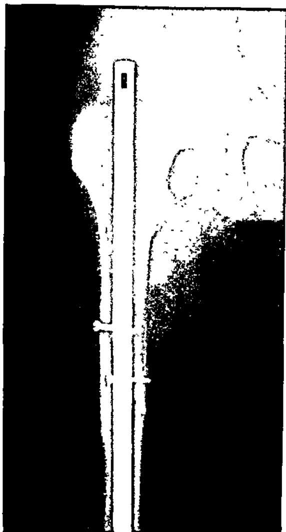


Fig. 10. Internal fixation of comminuted fracture of femoral shaft by means of intramedullary rod and two screws.

ton. This, in turn, produces hypercalcemia, and places an extra demand upon the kidneys. Occasionally, the kidneys are unable to meet this demand, and the so-called "hypercalcemic death of Paget's disease" may ensue.

Immobilization. Fixation can be obtained by four methods: 1. external fixation, consisting of a plaster of Paris cast or other adequate splint; 2. internal fixation: nails, intramedullary rods, screws, plates, pins, and the like (Figs. 10, 11); 3. a combination of internal and external fixation, consisting of pins in the proximal and distal fragments incorporated in a plaster cast (fixed traction) (Fig. 12). The Stader (11) or Roger Anderson type of external fixation splint, in which pins are applied to the proximal and distal fragments and then incorporated into a rigid connecting frame, has been used successfully (Fig. 13). 4. Balanced traction, which consists usually of skeletal traction on a pin introduced below the fracture site (in the tibial tubercle in the case of a fractured femur). Traction is used to overcome the pull of the deforming muscles, and, in the case of balanced traction, the extremity is usually supported in a cradling splint—such as a Thomas splint, or Böhler frame—and the traction applied by means of weights and pulleys. It is possible to maintain reduction in certain fractures using skin traction, but not in the case of most of the larger bones. The choice of the preferred method of treatment will be discussed under specific fractures in later chapters of the text.

Rehabilitation. In the foregoing, the first two of the "three R's of fracture management," namely reduction and retention (or immobilization) have been discussed. It is of the utmost importance always to keep in mind that the entire effort of the surgeon is directed toward returning the injured patient to the highest possible level of functional ability. Often it is tempting to lose sight of this ultimate goal, and to concentrate only on the treatment of an x-ray film or on the localized treatment of the fractured bone itself. From the very earliest stages of management, attention must be directed toward the mobilization and active exercise of all joints and muscles that are not, of necessity, immobilized because of the fracture. Regular exercise periods throughout the waking hours are of great help in preventing joint stiffness and the atrophy of disuse. The patient must be instructed in what he is to do, and subsequently must be asked to demonstrate his exercises. It is only in this way that the surgeon can be assured that his instructions have been well understood by the patient.

A patient who has fractured his left tibia and is confined to bed for 10 days to two weeks will be benefited by regular exercises to the uninjured leg, deep breathing exercises, and muscle strengthening exercises to the upper extremities and to the hip on the injured side. When he is allowed to become ambulatory, the usual weakness which accompanies bed rest will largely have been circumvented, and unnecessary and expensive hospital time spent in regaining strength will have been avoided.

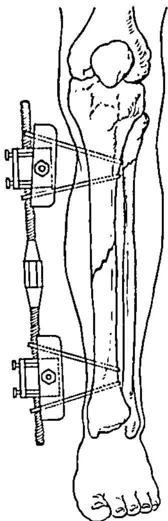


Fig. 13. Immobilization of fracture by means of external bar fixation.

x-ray, separation of the fragments but with no sclerosis of the bone ends, and no false joint.

Etiology of Delayed and Nonunion. The most common cause of delayed union and nonunion is inadequate immobilization. Interruption in blood supply accounts for other cases; lack of bone contact for some; and the presence of infection for still others.

Treatment of Delayed and Nonunion. In cases of nonunion, where there is actual sclerosis of the bone and a false joint, the treatment must be surgical if union is to be gained. This consists of freshening the sclerotic bone ends, of bridging the site with bone graft (13, 14, 15), and rigid immobilization or fixation. The type of immobilization or fixation must be adapted to the individual case. Delayed union, when it occurs, sometimes may be treated successfully merely by prolonging the period of immobilization. Occasionally, attempts are made to bring increased blood supply to the local area by means of multiple drilling of the proximal and distal fragments. The simple onlay bone graft of Phemister (16) has been used with success for many years. In the majority of cases of delayed union, the simplest and least traumatic procedure will give the most gratifying results.

STIFFNESS IN JOINTS. This complication is frequently the result of inadequate instruction to the patient concerning proper exercises during the period of convalescence. It may occur also as a result of splinting a joint in a position of strain. Stiffness may be the unavoidable result of severe fractures involving articular surfaces. Severe injury to the muscles and tendons scarred down by the healing process of a fracture, even though distant from the joint, may impair the function of that joint. This is seen particularly in fractures of the shaft of the femur, resulting in some unavoidable degree of limitation of motion in the knee joint (17).

MALUNION. As the name implies, malunion occurs when a fracture unites in a position of deformity. The causes here are inadequate reduction, inadequate fixation, mobilization prior to solid bony union, or unrecognized loss of reduction. The best treatment is prophylactic. Careful follow-up roentgen examination until union has become sufficient to assure maintenance of position is imperative and, in many instances, will obviate the embarrassment of malunion. Where it has occurred, malunion is usually treated by osteotomy and correction of the deformity.

DISLOCATIONS

Definition. Dislocation is a persistent displacement of the articular surfaces of a joint from the normal functional position (Fig. 14).

Pathology. ACUTE TRAUMATIC. Acute traumatic dislocation is characterized by a forceful stretching of a joint beyond its normal range of motion until there is tearing of the synovial and fibrous capsule and protru-

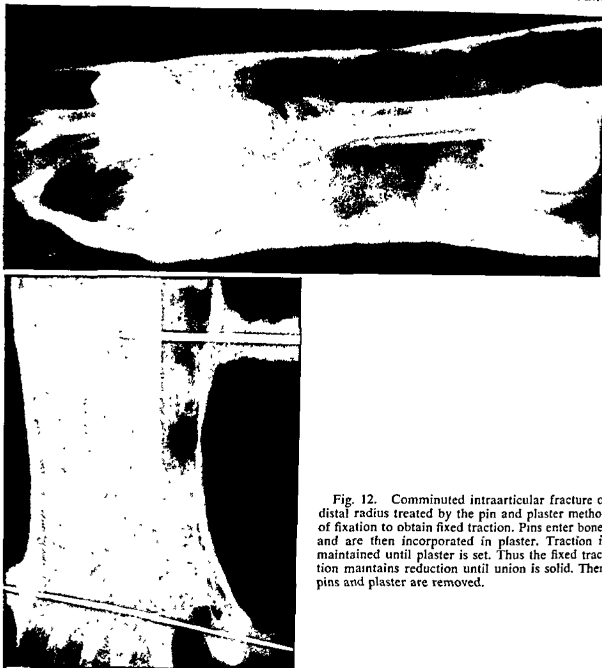


Fig. 12. Comminuted intraarticular fracture of distal radius treated by the pin and plaster method of fixation to obtain fixed traction. Pins enter bones and are then incorporated in plaster. Traction is maintained until plaster is set. Thus the fixed traction maintains reduction until union is solid. Then pins and plaster are removed.

room, with removal of devitalized tissue, dirt, and other foreign material, permits primary closure of the wound. In such cases, the percentage of successful results is high, especially with adequate systemic antibiotic therapy. Open fractures seen later than six hours after they have occurred should also be treated by débridement, but are better left packed open with vaseline gauze after reduction and then immobilized in plaster (12). Secondary closure may be attempted later. The appropriate time for secondary closure is when there is no longer danger of infection or, if infection has occurred, when it is under satisfactory control. Vigorous antibiotic therapy should be employed routinely in the management of these late cases, as well as in those seen prior to the optimum six-hour period.

Complications. NONUNION. Established nonunion is apparent when there is sclerosis of the fractured bone ends with bone laid down along the fracture line on the proximal and distal fragments and the formation of a false joint.

DELAYED UNION. Delayed union is characterized by persistence of the fracture line on

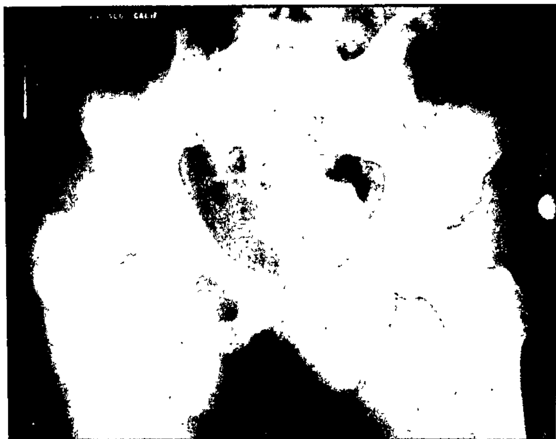


Fig. 16. Fracture dislocation of hip sustained in automobile crash. Patient was sitting with knee and hip flexed and struck patella on dashboard. Dislocation could not be reduced by traction without flexing hip.

tinuous muscle spasm about the involved joint; and point tenderness is not as striking as that seen in fractures.

ROENTGEN EXAMINATION. Roentgen examination is again of extreme importance; and again, two views are necessary (Fig. 15).

Treatment. After the diagnosis has been made and shock controlled, treatment of the local condition is undertaken as soon as possible. Because of the marked muscle spasm, reduction usually is accomplished with the least amount of trauma when an anesthetic is given. With the muscles relaxed, the limb should be placed in the position that it assumed at the time of the dislocation. Then gentle force should be applied in the *reverse* direction to the deforming force. This illustrates once more the importance of knowing the mechanism of injury (Fig. 16). The limb is then supported in a suitable splint until healing of the torn capsular and supportive structures has occurred. The length of time required for this healing varies with the magnitude of the torn structures but, in general, is about three weeks. The splint must be applied with the extremity in a position that will not allow recurrence of the dislocation.

The treatment of recurrent dislocation usually involves bony, ligamentous, or fascial reconstruction. It is quite detailed and can be found in other texts specifically devoted to the treatment of these injuries (Watson-Jones, 4, and Shands 9).

The treatment of open dislocations follows the general principles as set forth in the treatment of open fractures, but careful inspection must be made to ensure that no foreign bodies are retained within the joint.

SPRAINS

A sprain is a dislocation of a joint—usually partial—which has become spontaneously reduced. Partial tearing or complete tearing of the supportive fibrous, ligamentous,



Fig. 14. Subcoracoid dislocation, the most common type of shoulder dislocation.

sion through the tear of the dislocated distal or proximal articular surface. It is not uncommon that the major supporting ligaments are torn as well. Fracture of articular cartilage or adjacent bone may also occur with dislocation.

CONGENITAL DISLOCATION. Congenital dislocation is characterized by persistent displacement of the articular surfaces of a joint *without* a tear in the fibrous capsule. The most commonly seen congenital dislocation is that of the hip. Congenital dislocations are not the result of trauma.

RECURRENT DISLOCATION. In recurrent dislocation usually there has been damage to the articular rim of the adjacent structure so that the surface is flattened and shallow. Recurrent dislocation may also occur as a result of marked laxity in the fibrous supportive capsule or in the major supporting ligaments. It is characterized by repeated dislocation initiated by minimal trauma and represents basic instability of the involved joint.

Diagnosis. HISTORY. Just as in fractures, the history is a valuable tool in the diagnosis and treatment of dislocations, particularly in the importance of the mechanism of injury.

Examination. PHYSICAL. Careful physical examination is again of paramount importance, with particular attention necessary to the evaluation of the nerve and blood supply. Often shock accompanying dislocation is profound. Careful inspection and palpation will reveal that many of the characteristics of fracture are lacking. The deformity will always involve a joint rather than the bone itself. There will be no crepitus unless there is an accompanying fracture. There is marked and con-



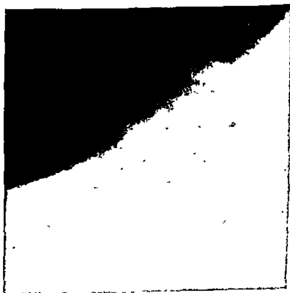


Fig. 15. Left, despite innocuous appearance on anteroposterior view, shoulder is dislocated posteriorly; right, lateral view of same shoulder showing humeral head posterior to glenoid.

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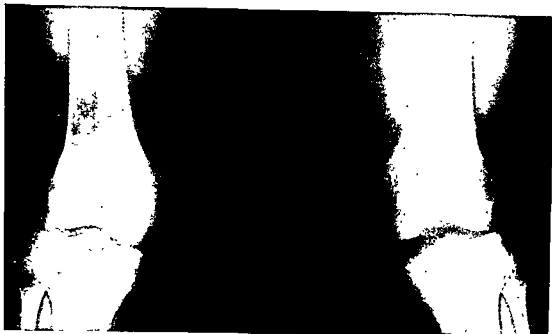


Fig. 17. Conventional x-ray studies were normal. Special x-ray shows two knees subjected to equal stress under anesthesia. The left knee demonstrates tear of medial collateral ligament.

and synovial structures usually occurs. Occasionally, the supportive ligament will avulse a chip of bone at its insertion or origin, instead of itself tearing.

The most common sprain is that of the ankle joint. Sometimes the pain is intense, but frequently it is not severe enough to prevent continued walking. However, if the patient sits down to rest for a short time, it is not uncommon that he finds, after this brief rest period, he is unable to bear weight upon the injured ankle because of the intense pain. Swelling is variable and may not appear for several hours. Ecchymoses may not appear for two to three days.

Treatment of sprains depends largely upon the severity of the injury. Cold compresses applied immediately for an hour or two will minimize the swelling. The joint should be supported in a position of maximal relaxation of the involved ligament. Frequently, this can be accomplished with adhesive tape strapping. In the more painful cases a more rigid support, such as a light plaster splint, should be used. As ligamentous healing and subsidence of pain occur, early motion is begun. When there is marked tearing and instability of the joint, surgical repair of the large supportive ligaments, particularly of such weight-bearing joints as the ankle or knee, is undertaken (18). In some cases, this can be determined only by examination under anesthesia with the aid of x-ray films taken with the joint in a position of stress. It is of prime importance to recognize these severe ligamentous tears and treat them accordingly (Fig. 17).

SUMMARY

The fundamental principles which should guide the surgeon in the diagnosis and management of fractures, dislocations, and sprains have been presented in this chapter, giving only general considerations. As A. Bruce Gill states: "Study principles rather than methods. A mind that grasps principles will devise its own methods." The usefulness of these principles will become abundantly apparent as they are applied to the diagnosis and management of specific fractures, as discussed in the ensuing chapters.

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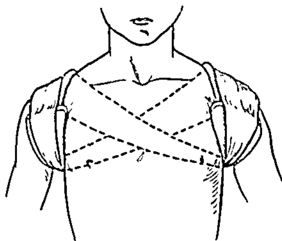


Fig. 2. Another method of immobilization in fracture of the clavicle, the figure-of-eight bandage; it is particularly useful in children. The dotted lines show how the bandage crosses on the back. The arm on the affected side is supported in a sling which is not shown.

posteriorly against the shoulder. To achieve this backward force, it is necessary to make backward pressure against both shoulders. For this reason, the Velpeau and Sayre dressings commonly used years ago for fracture of the clavicle have been abandoned; moreover, these dressings are usually very uncomfortable. Backward pressure against both shoulders with the thorax immobilized will result in satisfactory reduction in most cases. Under ordinary circumstances, the application of a figure-of-eight bandage with the shoulders held backward by assistants (Fig. 2) will maintain reduction sufficiently well to yield a good result. The axillae must be well padded with cotton and felt. A sling is necessary for the forearm on the side of injury to prevent downward displacement of the outer fragment. It will be necessary to check the dressing every two or three days to prevent dislocation of fragments.

In patients with badly displaced fragments, or in women in whom a good cosmetic result is desired, it may be desirable to apply a figure-of-eight plaster dressing which will maintain reduction more effectively. Here again, heavy padding is essential to protect the skin and axillae. As the plaster is setting, the patient should be lying supine with a small sandbag between the scapulas, and pressure should be maintained by the surgeon posteriorly against each shoulder. The cast should be trimmed to maintain pressure against the outer end of the clavicle anteriorly, but is cut away in the axilla to prevent undue pressure. The bandage or plaster cast should be left in place for three or four weeks in children and five to six weeks in adults.

On rare occasions, when displacement is marked and reduction impossible (usually because soft tissues are wedged between the fragments), an open reduction will be indicated. After reduction is achieved, position is maintained by heavy wire threaded through the medullary portion of the fragments.

In women or young ladies where the maximum cosmetic results are desired, absolute bed rest with no pillow, and with the arm in a sling offers the most satisfactory results. The patient is allowed up for bathroom privileges only. This routine, however, is very difficult to carry out because the patient will, in most instances, refuse to stay in bed. About four weeks' time is required for sufficient fibrous union to take place to prevent recurrence of the deformity; at the end of this time a Velpeau cast or bandage could be applied for further immobilization.

In transverse or oblique fractures with marked displacement, which either endangers the brachial plexus or threatens to perforate the skin, open reduction is sometimes necessary. The use of an intramedullary Kirschner wire or Rush pin is satisfactory in these cases for maintenance of reduction.

Dislocations of the Clavicle. The articulations at each end of the clavicle, though movable, are diarthroses and not true joints. Through injury of various types, the ligaments at either the acromial or sternal end may be torn. *Acromioclavicular* dislocation, however, is the more common of the two. The articular capsule is readily torn, but rarely does sufficient displacement occur to tear the coracoclavicular ligaments. If these ligaments are torn, wide displacement may occur. Examination rarely fails to disclose the true nature of the injury. The distal end of the clavicle is prominent and the acromion is depressed to a lower level. Tenderness and pain are present at this site. Abduction of the arm is painful. *Treatment* is best carried out by operative means but, if refused or impractical because of other injuries, external fixation will have to

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FRACTURES, DISLOCATIONS, AND SPRAINS: SPECIFIC TYPES

CARLO SCUDERI

Because of the gradually increasing number of automobile accidents, and the great number of injuries sustained in innumerable other types of accidents, fractures will continue to be a serious surgical problem. Although certain types of fractures are more common than others, fractures of almost every conceivable type can be produced. The complexity of the problems of reduction, bone healing, and the like, requires much training and experience on the part of the surgeon. In this chapter we will have space to discuss only the principles. The reader is referred to texts (1, 2, 3) and monographs (4, 5) for details.

THE SHOULDER GIRDLE

Traumatic lesions of the shoulder girdle are very common and include, primarily, fractures and dislocation of the clavicle, scapula, and shoulder joint.

Fracture of the Clavicle. This injury occurs most commonly in the middle third, and is encountered more often in children than adults. It is due to a transmitted force against the lateral side of the shoulder or to a direct blow on the bone itself. The important manifestations are pain, swelling, local tenderness, and deformity at the site of fracture. In children who have sustained a fall or similar injury and are reluctant to move the upper extremity, a fracture of the clavicle should be suspected; examination will usually reveal the primary manifestations mentioned above. The deformity is characteristic, the medial fragment being pulled proximally (cephalad) and backward (Fig. 1). The weight of the extremity pulls the outer fragment forward and downward. The fracture is usually oblique and overriding; comminution is not uncommon. Diagnosis is rarely difficult because the bone is subcutaneous throughout its entire extent. If there is a displacement of fragments there will be a shortening of the distance on the side of the fracture between the sternum and acromium, as compared to the uninjured side. X-ray films in the anteroposterior view reveal the lesion perfectly. On only rare occasions is the fracture compound; other complications are also uncommon.

Treatment consists of immobilization of the shoulder with force exerted upward and

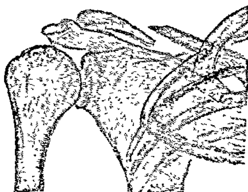


Fig. 1. Fracture of the clavicle at a common site. Sketch from an x-ray film, showing the usual displacement; the patient sustained this injury by falling on her shoulder.

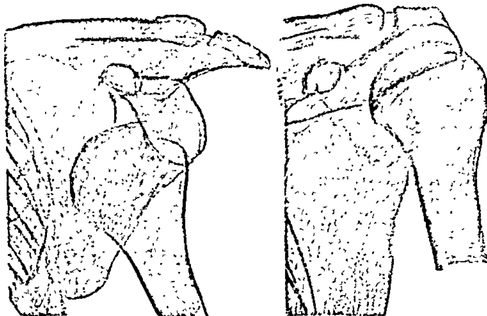


Fig. 3. Anterior dislocation of the shoulder in a 45-year-old laborer. Reduction was readily accomplished with the Kocher maneuver but recurrent dislocation finally necessitated an open operation.

hand. A characteristic sign is inability to touch the opposite shoulder with the hand of the injured side, maintaining the elbow in contact with the thoracic cage. There may be numbness of the ulnar side of the hand because of pressure of the head of the humerus on the brachial plexus. The axillary nerve may also be injured, with consequent paralysis of the deltoid muscle and inability to raise the arm at the shoulder.

Treatment consists of reduction of the displaced head. If the dislocation has just been sustained and inflammatory swelling has not occurred, reduction can be effected rather easily, but a general anesthetic is usually necessary in order to achieve muscular relaxation. The safest and most effective method of reduction is traction. Elimination of pain by ⅙ or ¼ grain of morphine will frequently be sufficient to attain reduction, although on other occasions an anesthetic will be necessary. In the traditional Kocher maneuver, which is losing favor, the upper arm of the patient is externally rotated. Reduction is then effected by adducting the arm, bringing the elbow forward and across the chest as the upper arm is internally rotated by bringing the hand of the patient over to the opposite shoulder. Another method consists of steady traction of the entire extended arm either in a longitudinal direction or at right angles to the body. After reduction, the arm is immobilized by bandaging it to the chest in a modified Velpeau fashion for two to three weeks, after which gradually increasing motion may be started. In dislocations of up to two weeks' duration the difficulty becomes greater, although reduction may still be effected in some cases up to two months. After this period, or when closed reduction is ineffectual, open operation is usually indicated. Factors leading to recurrence have been discussed by McLaughlin and Cavallaro (6).

Posterior Dislocation. This type of injury is rare; it is produced by falling upon the elbow with the arm rotated internally and abducted. The tear in the capsule occurs in the posterior portion and the head comes to rest at the posterior margin of the acromion (subacromial dislocation) or beneath the spine of the scapula (subspinous dislocation). Reduction is accomplished by down traction on the arm, and pressure on the head of the humerus in an outward and anterior direction.

Recurrent Dislocation of the Shoulder. If the tear in the capsule inflicted at the primary injury is large and healing is inadequate, the resultant scar may not offer sufficient support to prevent subsequent dislocation. *Subcoracoid* dislocations are most prone

be the method utilized. A felt pad is placed over the distal end of the clavicle and a band of adhesive anchored from the anterior chest over the pad to the back. The shoulder may then be lifted up by a strip of adhesive or modified Velpeau dressing with adequate padding under the olecranon. The outside of the dressing should be reinforced with adhesive in order to prevent stretching of the dressing with consequent loosening. To be effective, this dressing must be tight at all times and be worn for five or six weeks. It should be inspected every four or five days and reinforced or changed lest the shoulder be allowed to droop and tear the early fibrous union at the joint. Firm healing with correction of deformity is not always attained. However, the disability which follows is usually slight. Occasionally, when sufficient disability is present or when the coracoclavicular ligament has been completely torn, operative repair, requiring the use of fascial sutures or wires, may be advisable, although resection of the distal end of the clavicle is preferred by most bone surgeons.

Sternoclavicular dislocation is uncommon; when it occurs the sternal end of the clavicle is usually displaced upward and anteriorly. Tenderness and pain upon movements of the shoulder are present but not severe. If the dislocation is complete, operative repair is necessary. However, attempts at maintaining the reduction by loops of wire have usually terminated with the wire slowly cutting through the relatively soft bone, making a recurrence too frequent. Many surgeons advise resection of the proximal three-fourths inch to one inch of the clavicle; convalescence is short, and full activity of the arm is possible in less than three weeks.

Scapula. This bone is rarely fractured, and, if it is, the fragments are not usually displaced. The fracture may involve the spine, the glenoid, the supraspinous fossa, or the infrasupraspinous fossa. The clinical evidence of fracture may be very meager. If the fracture involves that portion of the bone not covered with much muscle, tenderness will be present and localized. Otherwise, the tenderness and pain will be diffuse, poorly localized, and perhaps mild. Immobilization in a sling or modified Velpeau dressing for three weeks is usually adequate treatment. Should there be much medial displacement of the glenoid fragment, five to eight pounds of traction in Buck's extension will reduce the fragments and maintain reduction with the arm in 90 degrees of abduction traction. If the surgical neck of the scapula is fractured, more disability will be produced. Motions of the shoulder joint in any direction will be painful. If the fracture is complete and displacement of the glenoid is present, reduction must be carried out. This is usually best accomplished by traction on the arm and manipulation. After reduction, it is usually advisable to put the patient to bed with his arm in traction in a Thomas arm splint for two or three weeks. Fixation in abduction for two or three weeks, perhaps with traction, may also be indicated in fractures through the glenoid fossa. Open operation is rarely necessary and is very difficult to perform because of overlying structures.

Dislocation of the Shoulder. This is the most common of all dislocations; it is due to transmitted violence which forces the head of the humerus out of the shallow glenoid depression of the scapula by tearing through the joint capsule.

ANTERIOR OR SUBCORACOID DISLOCATION. This is the most common type (Fig. 3) and is sustained by the patient falling on the hand or elbow with the arm abducted (6). The head of the humerus tears through the weakest spot in the capsule, i.e., at the inferior border. However, such a force more commonly results in a fracture of the head of the humerus, with which a dislocation is not infrequently confused and with which it may be associated. Clinical examination, however, usually reveals a characteristic deformity when a dislocation is present. The normal roundness of the shoulder beyond and below the tip of the acromion is lost so that the upper arm forms a straight line at a right angle with the axis of the clavicle (sometimes called deltoid flattening). The acromion is prominent. The axillary fold is depressed to a lower level. The head of the humerus can usually be palpated in its abnormal position beneath the coracoid, particularly if the arm is rotated gently. All the muscles about the joint are held rigidly. The arm is carried in mild abduction and the patient usually prefers to support the forearm with the opposite



Fig. 4. Fracture of the surgical neck of the humerus. Left, medial displacement of the shaft and some rotation of the head is noted. Closed manipulation was unsuccessful. At surgery the long head of the biceps tendon was found between the fragments. Right, end result. Six months postoperative. Reduction is excellent with good callous formation.

except that longer immobility is usually required.

Fractures of *the surgical neck* (Fig. 4) vary considerably in the type of fracture line (i.e., transverse, oblique, or serrated), and the amount of displacement of the fragments. When *complete displacement is present*, the end of the shaft fragment is often displaced upward into the axilla; the head is usually abducted and flexed and, in some instances, dislocated. The displacement of surgical neck fractures, if present, will depend on the site of the fracture and the muscles attached to the proximal fragment. The muscles which pull on the proximal fragment are the subscapularis, the supraspinatus, the infraspinatus, and the teres minor; those which pull on the distal fragment (Fig. 5) are the pectoralis major, the teres major, and the latissimus dorsi. Depending upon the activity of these muscles, the proximal fragment may be adducted or abducted in varying degrees or rotated internally or externally. It is often flexed forward as can be shown when lateral x-rays are taken. X-ray is decisive in determining the degree of deformity. The most common deformity is abduction and external rotation of the proximal fragment. The fracture is usually transverse, but may be oblique or comminuted. Disability is immediate and marked; swelling is apt to be masked by the deltoid and other shoulder muscles. Differentiation between fractures of the surgical neck of the humerus and dislocation is usually difficult to make except by x-ray because, in the acute cases, marked swelling from hematoma formation is present.

Treatment is different in the impacted type than in those with displacement. When impaction is present, treatment is limited to immobilization of the arm at the side of the trunk with a sling and swathe for 10 days to two weeks. During the following week, immobilization in a sling is sufficient, removing the arm two or three times every day for active motion; this active motion may be combined with gravity motion but not to a degree causing pain. The immobilization described above, even though moderate, may result in considerable limitation of the shoulder in the aged. Accordingly, particular attention must be paid to early active motion if the patient is elderly.

Treatment of fractures with displacement of fragments is dependent largely upon the age of the patient. In elderly patients, treat-

to recurrence; muscular strain on the extremity when the arm is abducted is one of the most frequent mechanisms. Recurrent dislocation can be prevented to a certain extent by binding the arm to the chest, but this entails *considerable inconvenience*. Operative procedures are usually necessary to correct the condition. A great many operative procedures have been recommended by various surgeons, but over the years most of them have been discarded.

The Nicola operation (7) has withstood the test of time and is a physiologic operation. The long head of the biceps tendon is cut just *proximal to its muscular attachment*, is put through a drill hole in the head of the humerus, and then resutured. The head of the humerus is kept in the glenoid cavity by the tendon which inserts into the superior margin of the glenoid.

The Roberts procedure is a modification of the Nicola operation, employing the same principle except that, instead of cutting the tendon and then threading it through the head, a piece of bone is removed; the tendon is dropped in this cavity, and the bone placed over it and sutured in place. This procedure is simpler, less time consuming, and does not entail threading the cut tendon through the drill hole in the head, which is difficult.

THE UPPER EXTREMITY

Fractures and dislocations of this part of the body will be considered under the following headings: humerus, elbow joint, forearm, and hand. In contrast to fractures of the lower extremity in which the function of weight-bearing is of primary importance, fractures of the upper extremity are of importance in relation to the finer movements, especially of the hand and wrist. Next in importance to the hand and wrist are the movements of the elbow, including pronation and supination of the forearm, whereas movements in the shoulder are the least essential. Another difference between fractures of the upper and lower extremity, *from the therapeutic standpoint*, is the importance of alignment; in the leg, good alignment is essential to satisfactory weight-bearing; but in the arm it is less necessary, although the correct carrying angle of the elbow must be maintained if the patient is to have maximum elbow *function*. *Fractures of the* upper extremity are less subject to muscle pull and the bones, being smaller than those in the lower extremity, heal more rapidly. Hence, immobilization is less prolonged, early motion more necessary and important.

Humerus. Fractures of the humerus are customarily divided into three groups: the upper end, the shaft, and the lower end (supracondylar). Their manner of occurrence is similar, i.e., they are commonly due to indirect trauma transmitted through the outstretched hand (3), although direct violence is occasionally responsible. Injuries to nerves are not infrequent in fractures of the humerus. Because of its close relation to the bone the radial nerve is most commonly involved. Brachial plexus injury is also seen.

FRACTURES AT THE UPPER END OF THE HUMERUS. Fractures at this site may be classified as those through the head and tuberosities, or those involving the surgical neck (8, 9).

Fractures *through the head* may involve one or both tuberosities. Local tenderness and pain on motion will be present, but a diagnosis can rarely be made without the x-ray, largely because deformity is absent or minimal. When the greater tuberosity is impacted into the adjacent bone (as by forced abduction), treatment is simple, requiring nothing more than a sling. When the greater *tuberosity is avulsed (as by forced contrac-*tion of the supraspinatus, infraspinatus, and teres minor muscles), treatment is more complicated because of the dislocation of the fragment. In such cases, reduction can usually be achieved by abduction and external rotation of the humerus. If reduction is not accomplished by this procedure, open reduction may be indicated. Fractures of the greater tubercle frequently occur with anterior dislocation; this occurs when the arm is forcefully abducted and externally rotated. Fractures of the *lesser tuberosity* (without involvement of adjacent bone) is uncommon; *it is due primarily to forced* pull by the subscapularis muscle. This fracture is often accompanied by a dislocation which must be reduced. Fixation of the shoulder as described elsewhere for the dislocation is usually adequate *for a fracture of the lesser tubercle,*

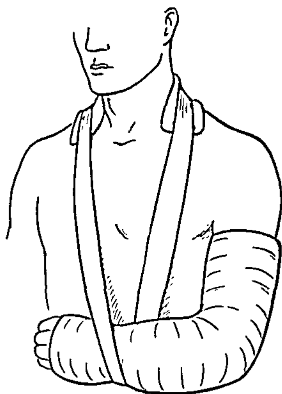


Fig. 6. Hanging cast, particularly adaptable for the ambulatory treatment of fractures of the shaft of the humerus.

elbow in about 90 degree flexion. Reduction may, of course, be indicated before the cast is applied. If the fracture is oblique, end-to-end reduction is often not possible. However, a hanging cast is still appropriate in the presence of overriding unless the fragments are separated. The cast should extend from the flexion crease of the palm up to the level of the fracture. If considerable overriding is present, the weight of the cast should be increased by making a thick cast. The cast is supported by a narrow piece of cloth or stockinet or a strip of gauze bandage. The patient must be instructed not to rest the cast on chairs, desks, and so forth, since this would destroy the traction. He must also be instructed to sleep in the sitting position. Should he lie down, the traction of the cast is lost, the fragments become displaced, and considerable pain ensues. A roentgenogram should be taken the day following application of the cast to determine position of the fragments, and repeated as indicated.

Frequently, considerable dislocation of fragments can be corrected by the hanging cast. If considerable dislocation remains after five or six days, then other methods of reduction should be undertaken—such as traction or bed rest (Fig. 7). In some cases, open reduction and internal fixation may be advisable (Fig. 8).

It must be remembered that, in the average adult, it requires eight to ten weeks to obtain a solid bony union. Immobilization of the fracture is essential until union occurs, to prevent angulation or displacement of the fragments and also to prevent pain and discomfort to the patient.

Nonunion of the humerus is more frequent than nonunion of the tibia. Bone grafting is necessary to correct this complication.

Radial nerve palsy occasionally occurs following fractures of the middle third of the humerus and, when it does, surgical exploration is indicated. Rarely is the nerve actually severed. Most of the time direct bone pressure on the nerve produces the paralysis which clears up in six to eight weeks after the pressure has been removed.

Radial nerve palsy as the result of callus overgrowth usually has an insidious onset and increases as the callus becomes larger. The callus must be removed and the nerve liberated as soon as the diagnosis is made, otherwise an irreversible paralysis occurs.

Supracondylar Fractures. This is a common injury during childhood and comprises fractures of the distal end of the humerus, nearly always transverse with displacement of the distal fragment backward and upward. Lateral displacement also occurs; only occasionally is the distal fragment displaced anteriorly. The force is nearly always transmitted to the elbow by a fall on the outstretched arm (usually with the elbow partially flexed). Examination reveals a deformity of the elbow which is apparent. The bony landmarks of the elbow are distorted, as may be best demonstrated by comparison with the uninjured side. Both olecranon and condyles are displaced posterior to the shaft of the humerus. At first glance, the deformity may appear similar to that produced by a posterior dislocation of the humerus, but examination will reveal the fact that the condyles are displaced backward with the olecranon, which does not occur in posterior dislocation. Swelling is rapid and usually intense, however, and

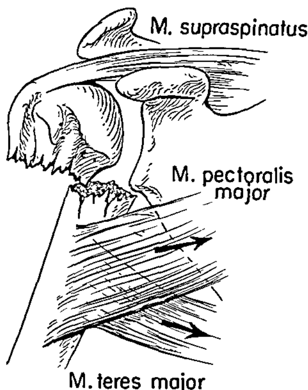


Fig. 5. Diagram of a fracture at the surgical neck of the humerus, showing a few of the various muscles which produce deformity. Most important of those pulling the upper fragment into abduction and flexion is the supraspinatus, as indicated. The teres major and pectoralis major adduct the distal fragment. Great variations exist; the position assumed by the fragments depends, in general, upon the relation of the line of fracture to the points of insertion of the various muscles.

ment as described above, without attempts at reduction, may be advisable. If the patient's physical reserve is not jeopardized by old age, reduction under anesthesia will be indicated. Reduction may be facilitated by strong downward traction on the arm while the proximal portion of the bone is pushed out with the hand in the axilla. If reduction is accomplished, its maintenance is secured by a pad in the axilla and by application of a sling with a body swathe in preference to any form of continuous traction apparatus or a cast. If reduction cannot be accomplished, operative intervention will be indicated. After reduction is achieved, immobilization may be maintained as above, perhaps utilizing the sling a week or two longer than mentioned above. Some surgeons utilize the hanging cast in such cases, but most prefer immobilization as described above.

Epiphyseal separation, while not common, is diagnosed only by the x-ray. It occurs only in children. Treatment requires accurate reduction and complete immobilization. If reduction is obtained and adduction of the arm against the chest wall does not disturb the position of the fragments, immobilization with the arm in a sling or bound against the chest with pads in the axilla is the simplest procedure if the child has minimal or no displacement. Should the child be difficult to control, then a Velpeau cast should be used for firmer immobilization. This immobilization should be maintained for four weeks or longer. Immobilization in abduction may, at times, be advisable for the first two or three weeks, particularly if it was necessary to abduct the shaft to achieve reduction.

FRACTURES OF THE SHAFT OF THE HUMERUS. Fractures of the shaft are not uncommon and occur by direct violence or by a transmitted force in falling with the arm outstretched. Transverse, oblique, spiral, and comminuted fractures occur, depending upon the degree and direction of the violence. Important is the fact that the radial nerve entwines around the shaft of the humerus at its mid-portion, thereby accounting for the frequency of radial nerve injury in this type of fracture. The deformity produced by fracture of the shaft varies and is dependent largely upon whether the break is below or above the attachment of the deltoid. If above, the upper fragment is generally pulled inward (adducted) by the pull of the pectoralis major, teres major and latissimus dorsi; if below, the deltoid generally abducts the proximal fragment. Overriding is due to the pull of all muscles acting longitudinally.

The clinical manifestations of fracture of the shaft are pronounced, the affected arm hanging uselessly, immobile, and completely disabled. The site of the fracture can often be detected by gentle palpation, preferably along the lateral aspect of the arm where the muscles are less prominent. Wrist drop, if present, is an indication of radial nerve injury. Sensory changes are rarely encountered; when present, they are very limited and inconstant in location over the dorsum of the hand.

Treatment of fractures of the humerus in the proximal third is probably most effectively carried out with a cast (10) (Fig. 6) with the



Fig. 8. Spiral fracture of upper third of humerus. Left, the sharp end of the proximal fragment was imbedded in the muscle tissue and could not be disengaged. Therefore, open reduction was indicated. Right, end result. Five months following surgery. Apposition is anatomic and function was excellent.

While traction is being maintained, the distal fragment is pushed anteriorly and molded into position. Reduction may be relatively easy, particularly in children. Immobilization is then instituted by bringing the forearm in as much acute flexion as is consistent with maintenance of a radial pulse. The flexion should never be so acute as to obliterate the pulse, because Volkmann's ischemic paralysis may rapidly follow, resulting from impaired blood supply to the forearm. If reduction has been accomplished, acute flexion is easy to maintain with very little force. If swelling is great or if the flexed position obliterates the radial pulse the *forearm must be extended until the circulation returns,* even at the expense of losing the reduction. If the patient complains of coldness, numbness, or tingling in the fingers at any time within two or three days following reduction, he should be seen immediately and, if circulatory impairment seems to exist, the dressings should be released or flexion decreased to allow adequate circulation. For this reason nothing should be placed in the fold of the elbow. If closed reduction is impossible, operation may be carried out; a simpler procedure is to insert a Kirschner wire through the olecranon for skeletal traction as recommended for intercondylar fractures or a picture-hook screw could be inserted into the olecranon and right-angle traction exerted on the elbow (Fig. 9). This has an advantage over the transverse insertion of a Kirschner wire through the olecranon because this latter procedure occasionally damages the ulnar nerve. If closed reduction is successful, fixation is achieved by a plaster splint which is molded along the posterior aspect of the arm from the axilla to the hand with the elbow in acute flexion and the forearm in supination. A bandage then holds the flexed arm to the side of the chest. Gradually increasing extension is begun in the second or third week. Seldom does any permanent disability result from this type of fracture, providing reduction has been achieved. This is explained for the most part by the fact that immobilization is carried out with flexion of the elbow and not extension. The most significant complication in adults is some permanent loss of extension. Children, as a rule, recover full elbow motion if the reduction is complete and maintained. The vascular and neural complications are ably discussed by Lipscomb and Burleson (11).

The Elbow Joint. Injuries to joints are of special significance largely because of the seriousness of damage to the articular cartilage. The nature and extent of the injury to the joint surfaces often determines the ultimate function of the joint, though it is often difficult to demonstrate clinically. The complicated structure of the elbow joint makes it

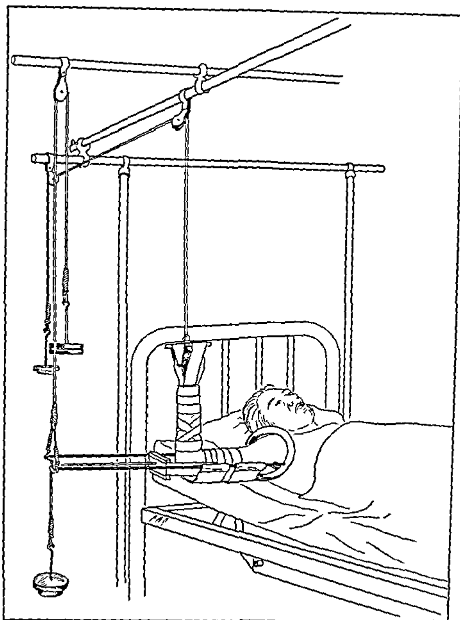


Fig. 7. Suspension and traction of the upper arm for fracture of the humerus. In this case traction is exerted by adhesive strips. When the fracture is close to the elbow, skeletal traction may be necessary; this is achieved by a wire or pin through the olecranon. Note the right angled flexion at the elbow, a position which is advantageous whenever possible because it produces less disability to the joint than that resulting from immobilization in complete extension.

tends to hide the type of deformity present. X-ray films in both views should be taken. Supracondylar fractures which involve the joint are discussed under the elbow joint.

Treatment consists of immediate reduction under complete anesthesia with fixation of acute flexion. This is performed even in the presence of severe swelling. Delay of even a few hours should be avoided. A delay of a few days is more serious because it allows the deposition of callus which will greatly interfere with subsequent replacement of the fragments and may make reduction impossible. The manipulations required depend on the position of the fragments but consist chiefly of traction. The method commonly described for reduction of supracondylar fractures is to exert traction on the forearm with the elbow extended. The authors, however, have noted that traction with the elbow flexed at a right angle is just as efficient, and apparently associated with much less trauma to the soft tissue.



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While traction is being maintained, the distal fragment is pushed anteriorly and molded into position. Reduction may be relatively easy, particularly in children. Immobilization is then instituted by bringing the forearm in as much acute flexion as is consistent with maintenance of a radial pulse. The flexion should never be so acute as to obliterate the pulse, because Volkmann's ischemic paralysis may rapidly follow, resulting from impaired blood supply to the forearm. If reduction has been accomplished, acute flexion is easy to maintain with very little force. If swelling is great or if the flexed position obliterates the radial pulse the *forearm must be extended until the circulation returns,* even at the expense of losing the reduction. If the patient complains of coldness, numbness, or tingling in the fingers at any time within two or three days following reduction, he should be seen immediately and, if circulatory impairment seems to exist, the dressings should be released or flexion decreased to allow adequate circulation. For this reason nothing should be placed in the fold of the elbow. If closed reduction is impossible, operation may be carried out; a simpler procedure is to insert a Kirschner wire through the olecranon for skeletal traction as recommended for intercondylar fractures or a picture-hook screw could be inserted into the olecranon and right-angle traction exerted on the elbow (Fig. 9). This has an advantage over the transverse insertion of a Kirschner wire through the olecranon because this latter procedure occasionally damages the ulnar nerve. If closed reduction is successful, fixation is achieved by a plaster splint which is molded along the posterior aspect of the arm from the axilla to the hand with the elbow in acute flexion and the forearm in supination. A bandage then holds the flexed arm to the side of the chest. Gradually increasing extension is begun in the second or third week. Seldom does any permanent disability result from this type of fracture, providing reduction has been achieved. This is explained for the most part by the fact that immobilization is carried out with flexion of the elbow and not extension. The most significant complication in adults is some permanent loss of extension. Children, as a rule, recover full elbow motion if the reduction is complete and maintained. The vascular and neural complications are ably discussed by Lipscomb and Burleson (11).

The Elbow Joint. Injuries to joints are of special significance largely because of the seriousness of damage to the articular cartilage. The nature and extent of the injury to the joint surfaces often determines the ultimate function of the joint, though it is often difficult to demonstrate clinically. The complicated structure of the elbow joint makes it

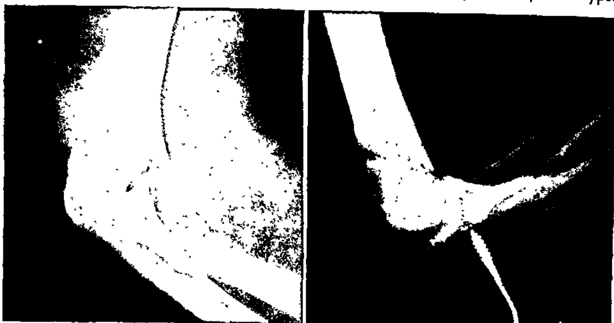


Fig. 9. Supracondylar fracture of the humerus. Left, note the superimposition of shadows which indicates overriding. Right, the reduction was obtained by skeletal traction. A picture hook screw was inserted into the olecranon and five pounds of traction applied, aided by Buck's extension. After four weeks of traction, a circular cast, axilla to hand, was applied for three more weeks before passive and active use was started.

particularly prone to disability because of the possibility of bony blocks due to comminuted *fragments which resist replacement.* As mentioned elsewhere in regard to the knee, aspiration of blood from the joint cavity has great *therapeutic value.*

Intercondylar Fractures. Most injuries of the humerus involving the elbow *joint are varieties of supracondylar fractures* which, in addition to the transverse break across the humerus, also exhibit a longitudinal *fracture into the joint, thus producing two or* more distal fragments. They are called intercondylar or *Y- or T-fractures* and, since they are produced by severe violence, are occasionally comminuted. The diagnosis depends on careful x-raying. Treatment, in general, is the same as that of supracondylar fractures, as already outlined. Immediate reduction, however, is frequently impossible because of the tendency of muscle pull and upward pressure of the olecranon, which maintains separation of the fragments. Continuous traction with a wire or a screw through the olecranon with the elbow at a right angle is to be recommended. In a few instances, the fragments will have to be approximated and held together by an open operation. This is a very difficult procedure as a rule, and the amount of joint fibrosis developing in the healing process always produces a *moderate to extensive loss* of all elbow motions. In going from one method to the other, time must not be lost *because of the rapidity with which the new* bone forms and hinders further procedures. In any event, immobilization in flexion is, *with few exceptions, the position of choice* in fractures into the joint, because it tends to maintain proper position of fragments. *Perhaps of more importance is the fact* that, if ankylosis should result, this position of flexion is much less disabling than that of extension, because a *patient does not* lose the ability to shave, wash his face, and so forth. As mentioned in the preceding section, it must be remembered that immobilization of the elbow in acute flexion may produce serious circulatory disturbance distal to the fracture with the consequent development of Volkmann's contracture. The precautions previously mentioned must be heeded vigilantly in any fracture about the elbow.

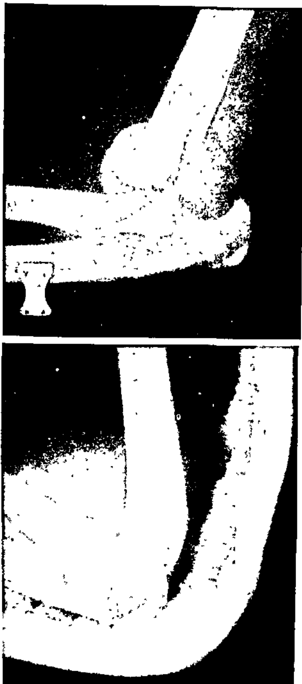
A second type of elbow-joint fracture is that of the *epicondyles.* Diagnosis is made by x-ray. Treatment is simple immobilization if there is no displacement. If the epicondyle is

displaced markedly, open operation obtaining fixation of the fragment with a screw, wire, or nail may be necessary. This is particularly true of the inner epicondyle which is often forced into the elbow joint. Important is the close relation of the ulnar nerve to the inner epicondyle; during the operation, the nerve may have to be transposed in order to avoid involvement in the callus.

Fracture of the Olecranon Process. This injury may occur because of a direct blow or because of violent contraction of the powerful triceps muscle. Since the anterior surface of this bone forms part of the elbow joint, just as does the patella in the knee, a complete fracture is associated with manifestations of acute synovitis and the elbow joint becomes filled with fluid and blood. The fragments, if separated, can easily be felt through the skin. Treatment, as in the case of the patella, is best carried out through open operation that enables evacuation of the blood in the joint and accurate approximation of the fragments, which are best held in place by stainless steel wire or a long screw passed through the olecranon down the shaft of the ulna. This is the preferred method if the olecranon fragment is not comminuted. Early mobilization is feasible without the possibility of displacing the fragments; moreover, joint motion more nearly approximates the normal. Postoperatively, the elbow must be immobilized at right-angle flexion, never in extension, otherwise useful flexion of the arm is frequently lost. If the fragments are fixed securely at the time of operation, the joint can usually be immobilized with at least a few degrees of flexion without endangering the position of fragments, thereby assuring earlier return of motion in flexion. It is important to begin active motion in two or three weeks in order to prevent delayed restitution of motion in the joint, i.e., limitation of flexion.

Dislocations of the Elbow. *Complete* dislocation of the elbow without fracture is produced usually by a fall on the outstretched hand with the elbow extended and, in most instances, is of the posterior type; the coronoid process of the ulna is displaced backward over the trochlear surface of the humerus so that it (the coronoid process) lies in the olecranon fossa. The radius of necessity is also dislocated or frequently fractured (Fig. 10). The deformity is striking; the displacement of the olecranon posterior to its usual position is pronounced. The bony landmarks are disturbed, i.e., the olecranon lies far posterior to the epicondyles when compared to the uninjured side. A moderate amount of medial or lateral displacement of the forearm is usually also present. The elbow is held in semiflexion and the slightest motion of the joint produces pain. Reduction should be immediate, under general anesthesia. Any medial or lateral displacement of the olecranon must be corrected. When the olecranon is in the straight posterior position, then the forearm is brought into acute flexion by traction on the forearm and thumb pressure directly on the olecranon. An audible snap or a palpable jumping of the olecranon into place assures the surgeon that reduction has been accomplished. If acute flexion without force, and a smooth movement of flexion and extension is possible, then a confirmation x-ray should be taken. Never should the patient be permitted to come out of the anesthetic, and the reduction considered satisfactory, until x-rays show this to be true. Immobilization in a cast from the axilla to the wrist is maintained for 10 to 14 days; then motion of the wrist is encouraged. *Fracture of the coronoid process* of the ulna is sometimes an associated injury. Its presence requires fixation in more acute flexion.

Dislocation of the Head of the Radius. This injury usually occurs anteriorly and is commonly, but not always, accompanied by a fracture of the upper third of the ulna. Flexion of the elbow beyond a right angle is not possible since the head of the radius impinges against the anterior part of the humerus. The elbow is held in a semiflexed position with the hand pronated. The head of the radius can usually be seen and felt anterior to its usual position. Reduction is best achieved under anesthesia by extension of the forearm, traction, and pressure in a posterior direction against the head of the radius. The forearm should be immobilized for three weeks in a cast with the elbow flexed and the forearm supinated. Difficulty in reduction is usually caused by portions of the articular ligament being displaced into the depression normally occupied by the head or by an unreduced ulnar angulation. In these



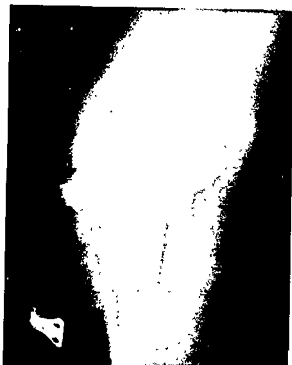


Fig. 10. Posterior dislocation of the elbow. Above left and right, in addition to the dislocation of the ulna, fragmentation and dislocation of the head of the radius is noted. Below, postreductive film. The loose fragments of the head of the radius were removed surgically to prevent loss of supination and pronation, which would result if they were left in. Fresh dislocations of the elbow are readily reduced by closed manipulation; operation is indicated only for complications such as occurred in this case.

cases, open reduction is necessary and can be accomplished only by shifting the interposing soft tissue back into its normal position. In young children, the entire head may be pulled out of its annular ligament by forceful traction of the forearm. In such instances, reduction is spontaneous or may be achieved under general anesthesia by manipulation during flexion and supination.

FRACTURE OF THE HEAD OF THE RADIUS. *The radial head really forms part of the elbow* joint moving against the capitellum of the humerus during flexion of the elbow and during supination and pronation. Fracture at this site is an important injury because of its importance in the motion of pronation and supination. Clinical manifestations include local tenderness, limitation of motion of the joint, and pain on performing these movements. An important diagnostic feature is the inability to pronate or supinate the forearm because of pain in the region of the head

of the radius. X-ray is essential to determine the degree and type of displacement which varies considerably. Mushrooming of the head with impaction of the shaft into it is a frequent deformity. In the extensive injuries, immediate operative removal of the head is advisable (12). With moderate displacement, open or, if possible, closed reduction with immobilization in flexion and supination is justifiable, particularly in growing individuals. If function remains impaired, removal of the head may be carried out later. When little or no displacement exists, treatment by immobilization without attempt at reduction may be preferable. As already mentioned, aspiration of blood in the joint will greatly hasten the reparative process and shorten disability.

The Forearm. The forearm, comprising the ulna and radius, is probably the most frequent site of fracture in the upper extremity; both bones often are involved. Forearm fractures are arbitrarily divided into fractures of the shafts of ulna and radius alone, or of both bones, and Colles' fracture. Of these, the last two are the most frequent.

FRACTURE OF THE SHAFT OF THE ULNA. This is not a frequent fracture and ordinarily presents no great problem in treatment since reduction of any displacement, if present, can readily be achieved by ordinary manipulation. Fixation in the mid-position with a cast, which immobilizes the elbow and wrist but leaves the fingers free, is maintained for five to six weeks.

The radial head is occasionally dislocated at the same time that the ulnar shaft is fractured. This is called a Monteggia fracture. It is obviously essential that this injury be detected. Reduction of the dislocation is effected first, before the ulna is manipulated, but replacement is sometimes dependent upon correction of the ulnar deformity. Open reduction is frequently necessary for the maintenance of the reduction of the dislocated head of the radius and the replacement of the ulnar fracture in anatomic reapposition.

FRACTURE OF THE SHAFT OF THE RADIUS. This is a common fracture, especially in children. (Those which involve the distal end are especially frequent and are considered separately under the heading of Colles' fracture.) Fractures of the radius are usually transverse and are most often located at the middle third or distal to it. Those in the proximal third are more rare. Displacement, if present, is usually confined to overriding or slight angulation. When the break is above the pronator teres, however, the proximal fragment is flexed and supinated, and hence markedly displaced. The treatment consists of reduction under anesthesia by manipulation and traction followed by fixation as for a fracture of the ulna. Fractures near the elbow will require sufficient flexion and supination at the joint to bring the distal fragment in line with the proximal. Fractures which resist attempts at closed reduction should be promptly operated upon and the fragments approximated under direct vision, fixed with a metal plate and screws or, in some instances intermedullary rod, and the arm immobilized.

FRACTURE OF THE SHAFTS OF BOTH ULNA AND RADIUS. The shafts of both bones of the forearm are more frequently broken than either alone, particularly in childhood. They are more difficult to manage than fractures of the radius or ulna alone, because of difficulty in achieving a good reduction of both bones (13). The force is usually direct or indirect by a fall on the outstretched palm. Considerable variation occurs in the severity of these fractures. Many are simple greenstick fractures of both bones, without displacement, but occasionally exhibiting considerable angulation. Many children sustain a complete and displaced fracture of one bone (usually the radius) with a greenstick of the other. In a considerable number both bones are broken and overriding or angulated, or both. The fracture may be compound.

Treatment consists of immediate reduction of the displacement, if present. The promptness with which reduction is carried out is almost as important in these fractures as it is in supracondylar fractures. If possible, the procedure should be instituted before swelling and muscle spasm have become pronounced, that is to say, within an hour or two after the injury. Greenstick fractures are readily reduced, although care must be taken to correct the angulation completely (Fig. 11). When overriding is present, a deep anesthesia is necessary with complete relaxation. It is particularly important in these fractures that the radius and ulna be kept from coming in con-

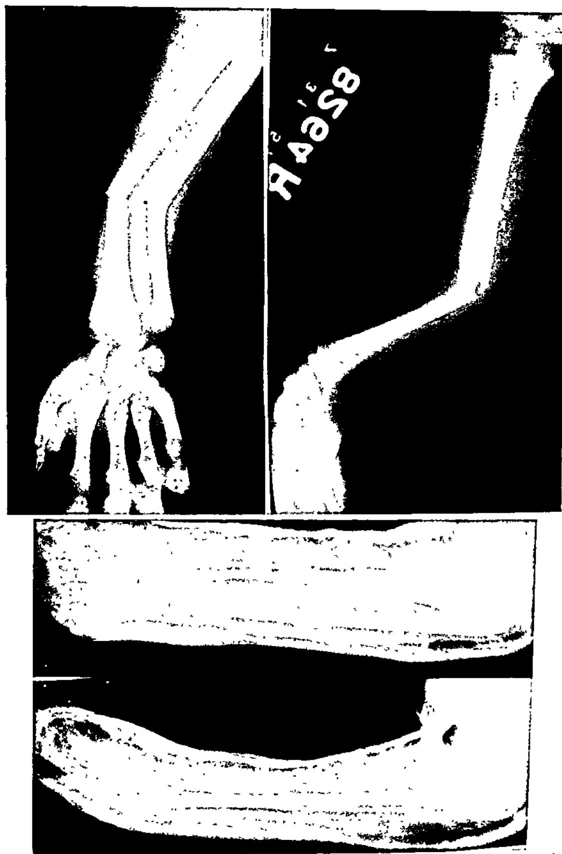


Fig. 11. Greenstick fracture of both bones of the forearm in a child, aged nine. Above, left and right, anteroposterior and lateral views reveal marked angulation deformity, but there was no false motion. Below, postreductive films showing arm in cast from knuckles to axilla. The forearm is in complete supination and right angle flexion at the elbow. The alignment of both bones is anatomic.



Fig. 12. Fracture of both bones of the forearm. A and B, anteroposterior and lateral x-rays reveal complete displacement of the bone ends associated with angulation and overriding. C and D, closed reduction of such fractures is almost impossible. A plate was used for the radius, whereas the ulnar fragments were held in place by a wire loop. Immobilization was maintained by a cast extending from the knuckles to the axilla with the elbow at right angle and the forearm in complete supination.

tact with each other across the interosseous membrane, lest a bony bridge grow across and seriously interfere with subsequent supination and pronation. This danger is revealed by appropriate x-rays which must show a clear separation between the two bones in at least one view. Reduction of these fractures is not easy. If either or both bones cannot be reduced, open reduction and internal fixation are strongly recommended (Fig. 12).

Another difficulty with fractures of both bones is preservation of reduction after it is achieved. This is due to the fact that external fixation is also a difficult matter in these injuries, particularly when the fracture is in the distal half of the forearm. The best position for immobilization is with the elbow at right angles and the forearm in supination or in semisupination (the mid-position with the palm perpendicular to the ground). The elbow and wrist must both be immobilized. The cast must be well molded and, after the plaster has set, it should be split on one side (usually the volar surface) from one end to the other to prevent any soft tissue constriction should subsequent swelling occur. Because reduction is often difficult to maintain, the site of fracture should be checked by x-ray in order to determine the position of the fragments during the first few days. The wrist is usually fixed in straight extension, but in fractures of the distal third it is often necessary to put up the forearm with the wrist in acute flexion in order to maintain the alignment and prevent volar angulation. After fixation in this abnormal position, for a week or 10 days, the forearm is then replaced in a straight splint for the remainder of the four- or five-week period.

Colles' Fracture. This is a common

fracture of the distal end of the radius and frequently involves also the styloid process of the ulna. The line of fracture is usually about 1 to 3 cm. from the articular surface. It is nearly always transverse with displacement and angulation of the distal fragment toward the dorsal surface, thus producing the well-known silver fork deformity. However, the fracture is not infrequently impacted and thus may show little or no deformity. In rare instances the distal fragment is displaced toward the palmar side, producing a reverse Colles' (Smith's) fracture. Deformity may be obscured if the patient is seen many hours after the injury because of the resulting edema and extravasation of blood. Palpation reveals the site of fracture rather accurately since the radius is superficial above the wrist; tenderness confined to the fracture site is a constant and important diagnostic sign. Point tenderness over the styloid process may also be detected. The history, moreover, is usually so characteristic as to lead to almost an immediate diagnosis in most cases. Colles' fractures are particularly common in older individuals, usually women, who fall and allow the weight of their body to be directed against the outstretched palm which is used to break the fall (Fig. 13). The impact produces forced extension and compression, transmitted to the distal end of the radius in a dorsal direction which accounts for the usual deformity. If the force is directed more in the axis of the forearm, an impacted fracture occurs. In children, the same force usually fractures the bones higher up; occasionally, however, there is an *epiphyseal separation*. The treatment of epiphyseal separation is the same as that of Colles' fracture.

Treatment is mandatory when angulation is demonstrable, even when the fracture is several weeks old. Otherwise, the patient will be unable to flex the wrist for proper function and a permanently weak, disabled, and painful hand will result (14, 15). Reduction, if performed early, is easy to effect and maintain, because of the absence of muscle pull on the distal fragment. Manipulation of a Colles' fracture should be preceded by straight traction as the least traumatic mechanism of breaking up impaction. Deep anesthesia for reduction is usually advisable but may not be necessary. Injection of novocaine into the site of fracture is often adequate. The distal fragment is molded and forced into alignment with the proximal radius, aided by strong flexion and ulnar deviation. If reduction is adequate, the hand will fall into a position equal to about 70 degrees flexion at the wrist as the forearm is raised. Immobilization is best achieved by a plaster cast but, if circular, it should always be split immediately after application to prevent damage to tissue by swelling. It need not include the elbow and should not extend down further than the metacarpophalyngeal joints. The desired position is moderate flexion with ulnar deviation. If the fracture has been reduced soon

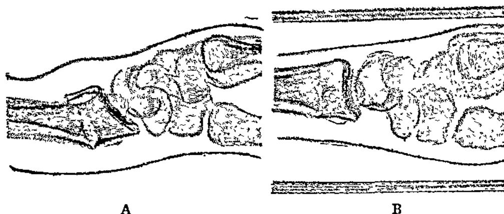


Fig. 13. Colles' fracture in an 80-year-old woman who fell on her outstretched palm. A, before reduction; note the typical silver fork deformity. There is only slight impaction in this case; B, after reduction, which was easily effected after the injection of 15 ml. of Novocain between the ends of the bone. Immobilization in an anterior and posterior splint; early motion was started on the sixth day.

after the injury and before much swelling has occurred, one must particularly watch for the danger of interference with the circulation by the cast (after edema and extravasation occur). If pain, swelling, and coldness of the fingers then develop, the cast must be split at once. Early active motion is desirable, but can rarely be started before there is some evidence of healing, lest loss of position result from the manipulation. Usually the cast can be removed in four to six weeks. Earlier removal of fixation all too frequently results in a recurrence of the original deformity, i.e., radial deviation of the wrist and posterior displacement of the distal fragment. Prolonged immobilization results in atrophy and restricted motion of the wrist. If good reduction is obtained, healing should be satisfactory and results good. Occasionally, poor results are due to injury involving the inferior radioulnar joint, a lesion which may be present in severe trauma and which requires accurate fixation.

The Hand. Under this heading will be included fractures and dislocations which involve the carpus, metacarpal bones, and phalanges. The wrist joint itself is rarely injured. The classification used will be a purely arbitrary one. It should be emphasized that all injuries of the hand are of special importance since the function of the fingers and wrist are so readily impaired. This is due to the relatively poor blood supply, the paucity of soft tissues, and the multiplicity of important structures contained in the hand (see also chapter on infections of the hand).

Fracture of the Carpal Scaphoid. A fall on the hand or a severe extension at the wrist may produce sudden pain, local tenderness, and swelling in the carpus which is often diagnosed as a sprain, but which is actually due to a fracture (Fig. 14). Any sprained wrist which has failed to heal within a reasonable length of time should be suspected of having a carpal fracture. Significant, if the scaphoid bone is fractured, is point tenderness over the bone which is best palpated on the dorsal surface in the floor of the triangle formed by the extensor and abductor tendons of the thumb (anatomic snuff box). X-ray,



Fig. 14. Fracture of the scaphoid (navicular) bone. A transverse fracture with good anatomic position is noted. Due to the poor blood supply, this bone has a high incidence of *nonunion, over 35 per cent.* Prolonged immobilization in plaster is necessary until x-ray union is visible. Frequently this may take three to five months.

however, is the only certain way of establishing the diagnosis. This is important because adequate treatment of this injury is essential if one is to avoid permanent disability (due to nonunion) which may follow an unrecognized fracture. There is rarely any displacement, merely a crack in the bone which, however, undoubtedly extends into and involves the articular space of the carpal joints. Oblique, as well as anteroposterior, and lateral x-rays may be necessary to make the diagnosis.

Treatment consists of prolonged and complete immobilization of the hand in dorsiflexion with the thumb fixed in wide abduction and the fingers flexed. This is continued for at least six weeks, even at the expense of the atrophy of disuse, since otherwise nonunion of the scaphoid bone and subsequent pain will result (16, 17). If the fragments are displaced, preliminary manipulation will be necessary. Although excision is sometimes advisable, drilling of both fragments and insertion of a bone graft into the drill holes should be tried before excision for cases of nonunion or asceptic necrosis. Good results with healing should be obtained in about 90 per cent of cases, but only if *early* recognition and early treatment are achieved; prolonged immobilization is also essential in order to avoid permanent disability.

DISLOCATION OF THE SEMILUNAR (OS LUNATUM) BONE. In forced hyperextension (dorsiflexion), the semilunar bone may be squeezed out of place and forced into the palm. The resulting deformity and local pain are usually sufficient to point to the seriousness of the injury and the x-ray easily reveals the nature of the lesion. *Treatment* consists of manual replacement of the bone under complete relaxation (general anesthesia) by hyperextension at the wrist accompanied by strong traction. Often a Thomas wrench may be required to achieve reduction. Immobilization in the mid-position for two weeks is adequate. Neglected dislocations or those impossible to reduce will necessitate open reduction or excision of the bone. The latter should be avoided, if possible.

FRACTURES OF THE METACARPAL BONES. These injuries are rather frequent but, since only a few are seriously displaced, they are rarely difficult to treat. The mode of injury is usually a direct force on the knuckles with the fist clenched. Transverse fractures, if displaced, are often merely angulated, usually toward the dorsal surface. Overriding is rare, but oblique fractures are not uncommon. Fractures accompanied by shortening can be detected by a loss of prominence of the corresponding knuckle. Deformity leads to disability and should be corrected. If angulation alone is present, it is usually in a dorsal direction and is best treated by immobilization in a dorsal splint which extends from the tips of the fingers to the mid forearm. With no displacement, a ball splint in the palm with the fingers fixed around it is adequate. When significant displacement is present, reduction is required before fixation. If manipulation is ineffective, operative reduction, perhaps with skeletal fixations, may be necessary. Usually, however, the universial splint of Allen and Mason (18) will be very appropriate (Fig. 15).

FRACTURE OF THE BASE OF THE FIRST METACARPAL BONE (BENNETT'S FRACTURE). This special type of injury (Fig. 16) is often overlooked or considered to be a sprained thumb, especially when swelling masks the deformity and diffuse pain interferes with accurate anatomic palpation. X-ray is, therefore, essential in the diagnosis. Significant displacement demands manipulation; fixation in wide abduction is essential and is best achieved with a plaster spica which embraces the wrist and thumb. Skeletal traction is usually indicated if closed reduction is not possible, the thumb being held in a position of 90 degrees of abduction. Dislocation of the proximal fragment occurs now and then and complicates therapy, which usually must be operative (19).

FRACTURES OF THE PHALANGES. Fractures without displacement are treated with simple fixation over a padded tongue depressor or, if several fingers are involved, over a ball which fixes the palm and digits in a semiflexed position; this position prevents volar angulation. If significant displacement is present, and attempts at reduction are unsuccessful, continuous traction in a modified banjo splint is used.

DISLOCATIONS IN THE HAND. In the wrist joint itself the inferior radio-ulnar joint is

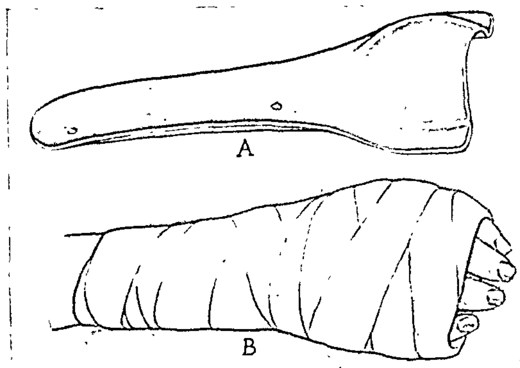


Fig. 15. *The universal hand splint* of Allen and Mason. The splint is made of aluminum and can be molded to fit the hand. It is particularly useful for fractures of the phalanges and metacarpals, maintaining the hand in a position of function.

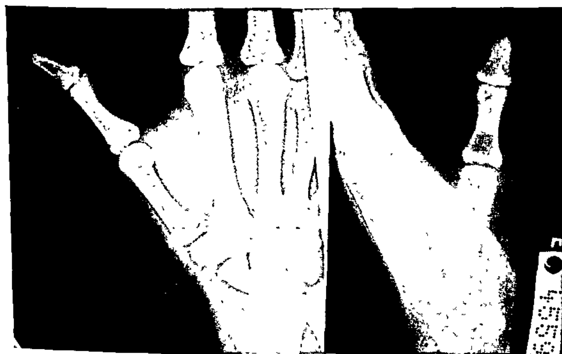


Fig. 16. Bennett fracture The fracture is located at the base of the first metacarpal. The thumb is in a position of adduction; if uncorrected, this would result in loss of ability to grasp large objects. The hand should be placed in a cast with abduction of the thumb for four to six weeks.

occasionally displaced and requires immediate reduction and immobilization; radiocarpal dislocations are even more rare and also require immediate reduction and fixation. Carpometacarpal dislocations are rare except that in the thumb the metacarpal bone may suffer a dislocation as well as a fracture. At the metacarpophalangeal joints dislocation is more common, at least in the thumb, and is due to forceful hyperextension with tearing of the anterior capsule. Reduction is not always easy and usually demands a general anesthetic; it can only be achieved by *increasing the deformity* (hyperextension) and by traction and direct pressure on the dislocated bone. Occasionally, interposition of joint capsule or of the flexor pollicis longus tendon of the thumb will prevent closed reduction and open operation must be carried out to remove the interposed tissue. Dislocation of the interphalangeal joints usually presents no great difficulty in either diagnosis or treatment. Reduction is usually easy by manipulation and traction in the line of the finger.

A special but frequent type of injury to the terminal end of the finger is mallet or baseball finger, trauma frequently being sustained by a baseball striking the end of the extended finger. The primary injury consists of rupture of the extensor tendon at or near its insertion, with a consequent subluxation deformity. Occasionally, a small chip fracture of the articular surface of the terminal phalanx is sustained. Treatment consists of immobilization with a wooden splint (tongue depressor) in hyperextension of the terminal phalanx, but function will be more completely restored by operative repair of the ruptured tendon with subsequent fixation for four to six weeks. This procedure, however, is technically difficult. The insertion of a fine Kirschner wire through the terminal and middle phalanges, then bending the wire to maintain the position of hyperextension, is probably the surest method of keeping the desired position during the healing process. Several very ingenious plastic apparatuses have recently been put on the market for keeping the terminal phalanx hyperextended and the middle interphalangeal joint flexed. Mechanically, these splints meet all the physiologic requirements for a successful outcome.

THE PELVIS

Fracture of the Pelvis. Fracture of the pelvis is usually sustained by direct impact of a crushing type from either the anteroposterior or lateral direction. Fractures through the rami of the pubis and ischium are perhaps most common (Fig. 17). Frequently, these fractures are bilateral. Another common injury is fracture through the ramus of the pubis and ischium with a fracture through the region of the sacroiliac joint on the same or opposite side. Because it is unprotected, fracture through the wing of the ilium frequently occurs. Fractures of the sacrum (usually in a transverse direction) and coccyx are important because of the tendency for such injuries to be followed by a chronic type of pain and backache, particularly in women. Although injury to the coccyx is frequently severe enough to expect a fracture, roentgenologic evidence of fracture is rare. Pain in the region of the coccyx is frequently spoken of as *coccygodynia* and may not be associated with any injury whatsoever. Because of resiliency maintained by the attachment of numerous ligaments and muscles to the pelvic ring, there is a strong tendency for fractured bones of the pelvis, even though displaced considerably at the moment of impact, to shift immediately into correct position. Obviously, if the injury is severe this spontaneous immediate reduction does not occur. As with other fractures, it is always important to search for injury to neighboring structures. Fractures of the pelvis may be accompanied by urethral, bladder, or intraabdominal injury. These associated injuries are considered separately.

Clinical Manifestation. The manifestations produced by fractures through the pelvic bones are extremely variable. When a fracture is sustained through the entire portion of the body of the *ilium* or through the region of the *sacroiliac joint* the patient is rarely able to walk. The pain in such instances is poorly localized and is described as being present over the entire side of the pelvis. If merely the *pubis* or *ischium* is fractured, walking may be possible, but will be painful. When the pubis is involved, pain and tenderness will characteristically be located in the groin. Ecchymosis will likewise appear in this region. Deformity will seldom be demonstra-



Fig. 17. Fractures of the pelvis. Arrows point to four fractures, the wing of the ileum, the acetabulum, the pubis, and the ischial tuberosity. The fracture was sustained several weeks previous to taking this x-ray.

ble except when there is a separation at the symphysis pubis, or when there is a fracture through the region of the sacroiliac joint with displacement. The amount of shock produced by fracture of the pelvis is variable, but may be considerable when the fracture extends through the supporting bones of the pelvis. Pressure on the anterior superior spines, or on the wing of each ilium simultaneously, will usually provoke pain if the pelvis is fractured.

Fracture of the *sacrum* is usually transverse and located in the lower portion. Dislocation of fragments is not frequent. Fracture of the *coccyx* is uncommon and is frequently associated with tearing of the ligaments supporting it. Diagnosis of fracture of the sacrum or coccyx is best made by x-ray, but digital examination through the rectum may be of value in revealing tenderness and extravasation of blood.

Fractures of the *acetabulum* are of two types, the most frequent being a fracture of the *rim or lip of the acetabulum* with displacement accompanying dislocation of the hip. As the head of the femur is being driven posteriorly and out of the acetabulum, the posterior lip of the acetabulum is carried with it. The *floor of the acetabulum* may be fractured and the head driven inward by a direct impact over the trochanter (such as occurs following a sideswiping automobile accident when the patient is thrown violently against the door), or by a fall with the patient landing on his feet. This type of fracture occurs chiefly in middle-aged persons, but is not common; in elderly people, the neck of the femur gives way before the floor of the acetabulum. There are few features diagnostic of this type of injury, although the patient is usually unable to walk and complains of pain upon motion of

the joint. There is no characteristic change in posture of the foot or other portion of the extremity, although slight shortening may be present.

TREATMENT. The type of treatment varies considerably, dependent upon the location of the fracture and the amount of dislocation of fragments. However, in a large percentage of patients the fracture is not complicated and no treatment other than bed rest up to six weeks in a firm bed with a fracture board under the mattress is all that is required. Attempts need not be made to reduce fractures of the rami of the pubis or ischium, even though considerable displacement of fragments exists. If there is a separation at the symphysis or a fracture through the body of the ilium with outward displacement, the pelvis should be suspended in a canvas sling, which tends to exert pressure inward from the sides. With fracture of a single ramus, bed rest for two weeks followed by weight-bearing on crutches for another four weeks is sufficient. If both rami on one side, or rami on both sides, are fractured, bed rest should be carried out for four weeks, and weight-bearing with crutches for another six weeks. Only on rare occasions is traction necessary.

If the fracture is located near the sacroiliac region and associated with much upward displacement of the pelvic fragment, reduction should be attempted. Such fractures are usually impacted so that simple traction will rarely be effective. The patient should be anesthetized and the impaction broken up (usually most effectively by forceful flexion of the thigh and adduction across the opposite hip). Heavy traction on the extremity is necessary to pull the fragments into position. This can be done readily by anesthetizing the patient on a fracture table and, with x-ray control, applying sufficient traction to reduce the fracture, then placing the patient in Buck's extension or Roger Anderson well-leg traction to maintain the desired position (Fig. 18).

Unfortunately, treatment of fractures of the *sacrum* is rather unsatisfactory without complete immobilization in bed. Adhesive splints and belts obviously do not offer much relief from the pain which may be present for many weeks unless the patient is confined to bed. Fractures of the coccyx, which are rare, are likewise benefited very little unless bed rest is obtained. Occasionally, if pain persists and is severe, removal of the coccyx may be indicated.

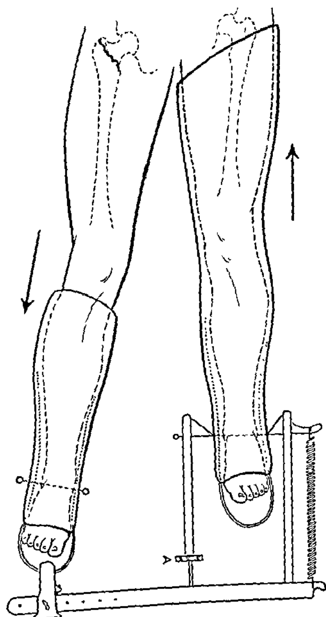


Fig. 18. The "well leg" Anderson traction (De Puy type). A steel pin is inserted through the tibia of the injured extremity and a plaster cast applied up to the knee; the yokes of one side of the splint are incorporated in the plaster. A plaster cast is applied to the uninjured extremity up to the hip, incorporating the yokes of the other side of the splint. By turning a screw pin at A, traction on the injured side is obtained by counterbalanced pressure upward on the uninjured side. Except for an occasional severe fracture of the pelvis, the use of this splint is confined chiefly to intertrochanteric fractures.

The treatment of fractures of the *acetabulum* is usually satisfactory if no displacement of the head of the femur or fragments of the acetabulum exists. Immobilization in traction in a Thomas splint for six weeks rarely fails to effect a satisfactory result. If, however, there is displacement of the fragments inward, permanent disability, including pain, may result unless the displacement is corrected. If the head of the femur is forced through the acetabulum, reduction can be achieved by traction, abduction on the upper thigh and prying the head outward; the fragments of the acetabulum usually will likewise be reduced. The insertion of an eight-inch screw with wide threads up the neck of the femur permits direct lateral skeletal traction. Usually 15 to 20 pounds of traction will reduce most central dislocations of the hip. If, in addition, 10 to 15 pounds of longitudinal traction is applied with a Buck's extension, excellent immobilization and sustained efficient traction can be obtained. Anesthesia is usually required for this reduction. Traction is maintained for at least six weeks. The patient may then be allowed up on crutches, but significant weight-bearing should not be permitted under 12 to 16 weeks. Displacement of the rim of the acetabulum may require open reduction.

Urinary Tract and Intraabdominal Injury. Tearing or puncture of urinary and intra-abdominal organs in fractures of the pelvis is surprisingly infrequent. Rupture of the bladder or urethra is the most common of these injuries and is usually produced, not by puncture, but by tearing of the structures at the moment of impact when displacement may have been considerable. Rupture of either of these two structures will be accompanied by urinary extravasation, intraperitoneal or extraperitoneal—usually the latter. The possibility of rupture of these two organs should be investigated at once. The patient is asked to void, and the urine examined for gross blood. Should the patient be unable to void, a soft rubber catheter is inserted. If a large amount of blood-stained urine is obtained, a rupture of the base of the bladder or urethra near the bladder is suggested, provided trauma to the kidney can be excluded. If only a few drops of bloody fluid are obtained by catheterization, there is a strong probability of a rupture of the bladder into the peritoneal cavity; evidence of intraperitoneal inflammation will, of course, be present. In this case, laparotomy for repair of the bladder is necessary. If the catheter cannot be inserted all the way through the urethra, and a few drops of bloody fluid are obtained, rupture of the urethra should be suspected; if present, suprapubic draining of the bladder is usually indicated to prevent serious extravasation about the urethra, scrotum, and anterior perineum. If extraperitoneal perforation at the base of the bladder exists, the application of a retention catheter usually is sufficient to prevent serious urinary extravasation. If urinary extravasation develops in spite of treatment, radical incisions may be necessary to prevent fatal infection and toxemia, although chemotherapy if started early will be of great prophylactic value (see also Ch. 41).

Any signs of peritoneal irritation in patients with fracture of the pelvis should obviously be viewed with alarm. Besides extravasation of urine from a ruptured bladder, the patient may have perforation of another viscus (particularly the intestine) or may have active severe hemorrhage. Abdominal pain, muscle rigidity, nausea, and vomiting are manifestations which should direct attention to the possibilities mentioned above. Laparotomy will obviously be indicated if perforation of the intestine, active severe hemorrhage, or intraperitoneal rupture of the bladder exists. It should be emphasized, however, that signs of peritoneal irritation may be produced by retroperitoneal hemorrhage alone, for which conservative care is indicated (see p. 812). Signs of paralytic ileus (distention and vomiting) may also be of reflex origin (see p. 826).

Sacroiliac Joint. Although strong ligaments (sacroiliac and sacrosciatic), and rough articulating surfaces allow but little motion in the sacroiliac joint, it is a true articulation since it is lined with fibrocartilage. The mechanism of production of *sacroiliac sprains* is not clear. Child-bearing, unusual strains, and the like, may be etiologic factors, but frequently there is no discernible etiologic agent. Occasionally, the disease is cured by eradication of a focus of infection, suggesting that infection may at times be important in the pathogenesis. There appears to be no doubt that occasionally there is actually a slip in the

position of the articulating surfaces so that a definite subluxation exists.

The *manifestations* are varied. The pain is usually unilateral, confined chiefly to the region of the sacroiliac joint, but may be located in the lumbosacral region or down the course of the sciatic nerve. The patient usually experiences considerable pain when stooping. Attempting to touch the floor with the hands is particularly painful. The disease may develop suddenly with severe pain and complete disability or may appear gradually with only mild symptoms. The pain may be transmitted to the abdominal wall, and if on the right side, may simulate acute appendicitis. The duration of the disease is likewise extremely variable. Tenderness over the sacroiliac joint is usually demonstrable. Muscles about the joint may be spastic.

Treatment is frequently unsatisfactory, but one of the most important factors in the treatment of the acute cases is rest in a hard bed equipped with a fracture board. This simple type of therapy, supplemented with the application of local heat and massage by a competent physical therapist is frequently followed by a cure in a week or two. Occasionally, the application of a lumbosacral canvas back support with two rigid ten-inch metal stays offers considerable support and relief when the patient is up and about. There seems to be a growing belief that at least a mild dislocation of the articulating surfaces exists, and for that reason manipulation should be performed, particularly in the stubborn cases. The exact mechanism or maneuver in this manipulation which effects relief is poorly understood, but the fact remains that manipulation is frequently followed by remarkable relief, particularly in those with no "sciatic" pain (Jostes, 1938). In the severe cases, fixation of the pelvis and extremities in a plaster cast for a few weeks should be tried. On many occasions, even in severe cases, the pain leaves as suddenly as it appears, which suggests the presence of a neurogenic factor.

Lumbosacral Sprain. Sprains in the lumbosacral region may likewise be acute or chronic. Usually, the pain comes on suddenly while the patient is performing some simple action such as stooping to the floor and lifting a very light object. People who lead a sedentary life as far as graded, routine exercise is concerned are most apt to be afflicted with the disease. Faulty posture may be of etiologic significance, and at times may be so pronounced as to allow deviation of the lumbar axis so far from the horizontal plane as to allow a slipping forward of the last lumbar vertebra on its sacral articulation. Protracted cases may be associated with congenital anomalies, involving, for example, the transverse processes or articular facets.

Pain is located in the lumbosacral region and radiates outward in all directions but rarely extends down the thigh. Occasionally, abdominal pain is present, thus adding to the diagnostic difficulty. The patient is unable to stoop over except by flexion at the hips. The spine is usually rigid throughout the entire lumbar region (poker spine). Mild tenderness is present over the lumbosacral region, but proportionally much less than the pain. During the first few days, the pain is frequently so severe that the patient is unable to get out of bed. On many occasions it is very difficult to distinguish lumbosacral sprain from a dislocated intervertebral disk (see also Ch. 24).

Treatment during the acute stage of the severe cases consists of rest in a bed fitted with a fracture board; in severe cases it may be necessary to apply a plaster cast extending from the mid-thoracic region down to the femoral trochanters. If recovery is slow, the cast may be substituted for a stiff supportive jacket. The daily application of heat, by a bake or otherwise, adds much to the patient's comfort and no doubt facilitates healing. The patient may have to wear a lumbosacral support of some kind for many weeks or even months. He should be instructed not to lift heavy objects until he is completely well. If pain and disability become prolonged, such operative procedures as spinal fusion may be indicated. In all of these cases the possibility of a dislocated intervertebral disk (nucleus pulposus) must be kept in mind as a cause of symptoms. Many patients with low back pain are markedly improved or even cured by manipulation; the explanation of relief by manipulation is not clear since not all patients relieved have actual dislocation of bony structure.

THE LOWER EXTREMITY

There are numerous features about fractures of the lower extremity which are peculiar to fractures in this location; these features must be constantly borne in mind if good results are to be obtained (20). For example, the bones which are associated with weight-bearing must obviously be immobilized longer than other bones. Furthermore, it is particularly important that correct alignment with proper position of fragments be obtained and maintained, because alignment vitally affects the function of weight-bearing; subsequent pain and disability are apt to be severe if position and alignment are not good, chiefly because of disturbances in the line of weight-bearing. In the anteroposterior plane, the line of weight-bearing should pass from the anterior superior spine and cross the patella extending downward to the interdigital space between the large and second toe. In the lateral plane, the weight-bearing line should pass from the great trochanter downward through the head of the fibula and external malleolus (Fig. 19).

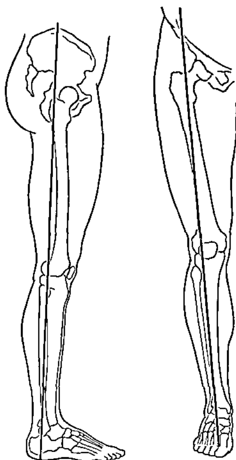


Fig. 19. Lines drawn through the bones of the lower extremity showing the optimum axis of weight-bearing.

Neck of the Femur. Fractures through the neck of the femur are to be considered serious, not only because of their frequency and high initial mortality (up to 25 per cent) but particularly because of the high incidence of nonunion. A high incidence of 30 to 40 per cent nonunion often followed the old closed reduction methods. Nonunion has been considerably reduced by the introduction in recent years of methods of internal fixation, as will be described later. Fractures of the neck of the femur are intracapsular, i.e., medial to the attachment of the capsule of the hip joint. Dislocation of fragments is variable. The explanation for the frequency of nonunion in fractures of the hip lies in the fact that the blood supply of the head of the femur is seriously impaired by fracture of the neck, particularly when the break is intracapsular, because the ligamentum teres is then the sole source of nourishment; in many instances, the head of the femur receives no blood supply whatever through the ligamentum teres (Fig. 20). Because of the more profuse though still meager blood supply furnished by the joint capsule, union is much more apt to occur if the fracture is distal to this point, i.e., extracapsular. The outlook as to union of fragments is much more favorable if impaction is present.

Fractures of the hip are most common after the age of fifty and are particularly prone to occur in women. A variable amount of shock may be produced in these patients, even though the fracture may be sustained with no more injury than a fall to the ground from a standing position and presumably occurs in most instances by direct impact on the great trochanter. In many instances, the fracture is the cause of the fall and not the result, particularly in the aged. Decalcification and other organic changes incident to old age may make the bone so weak and brittle that a sudden twist or strain on the hip may result in fracture at the weak point, namely, the neck of the femur.

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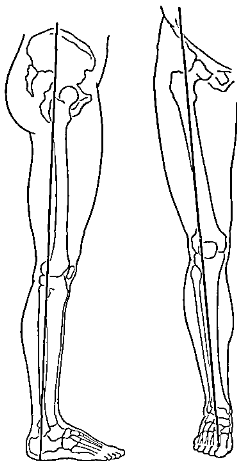


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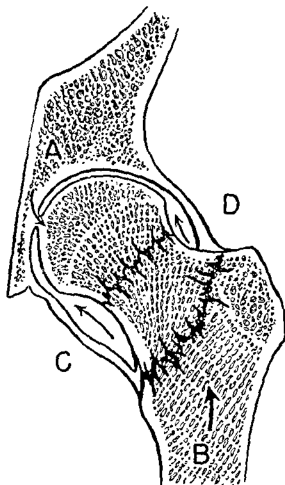


Fig 20. The role of blood supply in healing of fractures. Although an intracapsular fracture rarely occurs simultaneously with an extracapsular fracture as shown in the illustration, they are illustrated together to show the difference in blood supply at the two levels. The blood supply of the proximal fragment at the level of the intracapsular fracture is very meager, consisting only of the inadequate supply coming through the ligamentum teres, thus accounting for the high incidence of nonunion with this type. When the facture is extracapsular, the medullary blood supply (B) is very abundant and the capsular blood supply (C and D) is of value in maintaining adequate blood supply in the proximal fragment to allow healing.

CLINICAL MANIFESTATIONS. Invariably the patient is unable to walk, except in the occasional instance when the fragment is solidly impacted. In the absence of impaction, a rather typical deformity is usually present. The leg is externally rotated, the thigh slightly abducted, and the knee flexed not more than a few degrees if at all. Comparative measurements of the extremities from the anterior superior spine to the internal malleolus will reveal a shortening up to a few centimeters on the injured side. The base of Bryant's triangle will be shortened over that of the normal side and the trochanter will be above Nélaton's line (Fig. 21). There will, of course, be no shortening in the measurement from the great trochanter to the external malleolus. To avoid error, all measurements involving comparison of the two extremities must be made with the uninjured extremity in the same position as the injured. It must be remembered that the results of the measurements just mentioned may be the same in a dislocation of the hip as they are in fractures of the neck of the femur, but in dislocations the knee remains in considerable flexion which cannot be overcome by force. The amount of pain will be variable, but frequently is trivial; it will naturally be increased markedly upon motion. Tenderness is diffuse over the region of the hip. Rotation of the thigh will reveal the fact that the trochanter turns in the palm of the hand instead of rotating in a large arc, as is the case when the neck is intact. Such maneuvers as traction on the extremity or pressure upward on the heel will reveal changes in the measurement between the anterior and superior spine and internal malleolus. However, these maneuvers usually produce so much pain as to be justifiable only in patients with nonunion. If the fracture is impacted, there may be only minimal deformity or deviation in measurements from the normal side. However, fracture with impaction is often associated with a valgus deformity. If examination is painful, it should be omitted and an x-ray taken, thereby enabling one to discern the exact extent of injury. An x-ray is particularly indicated in injuries about the hip, especially in elderly people, since disability and other evidences of fracture may be slight if impaction is present; moreover, the clinical diagnosis may be inaccurate when an impacted fracture is present.

TREATMENT. In many instances, *emergency treatment* can be instituted before arrival at the hospital. The most important feature in emergency therapy is fixation of the extremity, thereby preventing movement of the fractured ends upon each other which is painful and contributes to shock. One of the best agents available for obtaining fixation in these emergency situations is the Thomas (full-ring) or Keller (half-ring) splint. If one

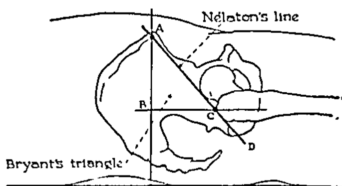


Fig. 21. Bryant's triangle and Nélaton's line. The triangle is drawn (with the patient lying supine) by dropping a perpendicular from the anterior superior spine, and carrying a second line BC, from the greater trochanter, perpendicular to this line. A third line, AC, connects the spine and trochanter. If the line BC is shortened over such a line drawn on the opposite side, an upward displacement of the trochanter, such as would be produced by a dislocation or fracture of the neck of the femur, is indicated. Nélaton's line AD extends from the anterior superior spine to the ischeal tuberosity, and normally should pass through the tip of the greater trochanter. If the greater trochanter lies above this line a dislocation or fracture of the neck of the femur probably exists.

of these is not available, a Liston board splint extending from beyond the foot to the axilla should be applied. A hypodermic of morphine will be effective in eliminating pain and minimizing the development of shock. The splint should be left on during transportation of the patient to the hospital and even while the initial x-ray is being taken. If the patient is in shock, treatment of the fracture should be postponed until the shock is relieved.

The closed method of treatment with a plaster cast has been supplanted entirely in recent years by operative fixation of fragments (Fig. 22) by means of some type of nail or pin (21, 22, 23). This method has the great advantage of requiring no external fixation;

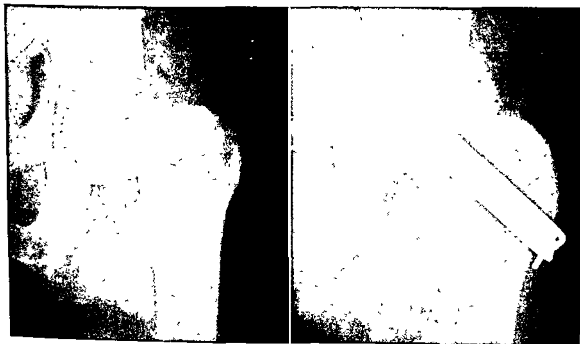


Fig. 22. Fracture of the neck of the femur. Left, three major deformities consisting of coxa vara, shortening, and external rotation of the leg are present. Right, postoperative films. After insertion of a pin, all deformity has been corrected.

it shortens the period of bed rest, allowing weight-bearing much earlier. These two factors are very desirable not only from the standpoint of the patient's health and comfort but are also very conducive to healing of the fracture. In the hands of well-qualified surgeons, the incidence of solid bony union with no complications is about 85 per cent. Early complications are infection, inadequate reduction, and "incorrect pinning." Late complications are "backing out" of the pin, with loss of adequate fixation, and aseptic necrosis of the head.

Several methods of inserting these pins or nails have been described. Regardless of which method is used, reduction must first be obtained. In order to first achieve good reduction, manipulation is carried out, under a local or general anesthetic, by the Leadbetter (24) maneuver, which is an excellent method of correcting the displacement. This maneuver consists of manipulation with the hip and knee flexed and the pelvis fixed; while the leg is in this position, traction is exerted upward on the thigh which is gently rotated internally to engage the fragments. When the reduction is effected, the hip is brought out into extreme abduction with the foot and leg in internal rotation, fixation of the pelvis being maintained by abduction of the other thigh. An efficient reduction is indicated if the heel of the affected leg will remain in the palm of the surgeon in an abducted and internally rotated position (heel-palm test).

One method of internal fixation consists of making an incision one or two inches long over the trochanter, and inserting two or three heavy wires through the trochanter into the head of the femur by means of a drill. A Smith-Petersen nail of proper length is threaded over the wire, which is shown by x-ray to be in the best position, and driven through the trochanter into the head to obtain complete fixation. Some surgeons prefer to drive the nail without the aid of the guide wire, particularly if a protractor is used to guide the direction of the nail. Regardless of the method of nailing used, the x-ray will be of inestimable value in determining whether or not the position is satisfactory. A lateral as well as an anteroposterior x-ray is necessary. These x-rays should be made, developed, and read after reduction and before incision has been made. They should be repeated and read after the internal fixation material is in place and before the wound is closed. After closure of the wound the patient is placed in bed with the affected leg suspended with the aid of a few pounds of traction for about four weeks, after which time he may be allowed up, using crutches for a period of four to six months, permitting only slight weight-bearing at first. The nail need not be removed unless complications develop.

Instead of using a large nail as a means of internal fixation, more recent procedures have employed four smaller pins (Moore) threaded at the end, which engage the head of the femur. Ordinarily, the x-ray will be of value in determining whether or not union is taking place insofar as decalcification with decrease in density takes place in the head of the femur under normal circumstances of healing.

Another modification of internal fixation, using an originally designed incision and flange as reported by Cubbins, Callahan, and Scuderi (25) is very satisfactory. Even though the incision appears extensive, incising the capsule and allowing full view of the fracture line, they report only one death in 105 patients operated upon; union was obtained in 90 per cent of the fresh fractures. The incision has an important advantage insofar as pieces of periosteal synovial membrane, which might lodge between the bone fragments and encourage nonunion, can be seen and removed. The incision has an added advantage in that the extent of reduction by the Leadbetter maneuver can be observed.

If the x-ray shows signs of necrosis of the head, or erosion of the neck of the femur, protection by means of the caliper splint will have to be extended and weight-bearing postponed for several months. The insertion of bone grafts into the area of aseptic necrosis aids in the revascularization of the area, and many aseptic necrotic heads can be salvaged. This is especially important and should be recommended in the younger group of patients (i.e., 60 years of age or younger). Phemister has discussed the features of aseptic bone necrosis in detail. X-ray changes, including increased density of the head, may be the first evidence of necrosis.

As already mentioned, *nonunion* in frac-

tures of the neck of the femur occurs frequently, even when treated in expert hands, although the incidence has been reduced sharply by internal fixation. However, a positive diagnosis of nonunion cannot be made earlier than six months after the injury, even with the aid of the x-ray. Nonunion is suggested in the x-ray by an absorption of bone at the line of fracture, but particularly by a more dense appearance of the head of the femur, or at the fracture line. This apparently paradoxical condition (viz., increased density of the head of the femur associated with nonunion) is due to the fact that normal bones with adequate blood supply always exhibit decalcification following immobilization. The absence of the absorption of calcium, therefore, is indicative of inadequate or absent blood supply.

Five major operative procedures are available in the treatment of nonunion of fracture of the neck of the femur.

1. Internal fixation, using nails or pins as described for the treatment of fresh fractures, may be successful, but obviously in a lower percentage of cases.

2. A bone graft may be inserted through the trochanter into the head, a procedure more difficult than nailing, but perhaps associated with a higher percentage of success.

3. The Brackett operation may be very successful if the head is viable. The operation consists of excavating the central portion of the head of the femur and inserting the fashioned end of the shaft. The trochanter must be cut off and transplanted lower down to avoid interference in motion. Weight-bearing is permitted in eight weeks.

4. The Whitman operation, consisting of removal of the head and insertion of the fashioned end of the shaft into the acetabulum with transplantation of the trochanter and its attached muscles as in the Brackett operation, may be very adaptable, particularly when any of the other procedures for nonunion have resulted in failure. This operation always leaves the patient with a bad limp and a moderately painful hip and should only be used if at least 1.5 inches of the neck is available to be rounded off and placed in the acetabulum.

5. Osteotomy (cutting through the entire thickness of the shaft), either high or low, may be performed to eliminate shearing action at the fracture and to bring the line of weight-bearing at a right angle to the fracture surfaces. This operation is less extensive and shocking than the reconstruction procedures and may be employed in patients who would not stand more extensive operations.

6. The substitution stem prosthesis has become very popular, and the results have been most gratifying. Excellent end results up to five years have been reported. No one knows how long these hips will continue to function satisfactorily. Some men are advocating this in all fresh fractures of the neck of the femur in the older age group (75 and above) because the postoperative convalescence is short and ambulation early, usually four to six weeks after operation.

The choice of the six procedures will depend largely upon the features of the case under consideration. It must be remembered that some of them are quite formidable procedures and will not be tolerated by patients who are poor risks, particularly the aged. Moreover, the fixation incident to fibrous union not infrequently will eliminate most of the pain and disability of nonunion, and will contraindicate any operative procedures, particularly in the aged.

Dislocation of the Hip. Dislocations of the hip are relatively uncommon and are of two types; namely, posterior and anterior (Fig. 23). By far the majority are of the former type. Occasionally they are complicated by fractures of the acetabulum, consisting usually of merely the rim of the acetabulum (see p. 491).

A complication of dislocation of the hip only recently appreciated lies in the possibility of aseptic necrosis of the head of the femur (Phemister, 1934), a phenomenon which occurs, however, more commonly in fracture of the neck of the femur.

Posterior Dislocation. The mechanism producing this type of injury usually consists of an upward thrust on the knee with the thigh flexed, adducted, and rotated internally. The head of the femur is forced through the posterior capsule and lies on the ilium posterior to and above the acetabulum. The deformity, consisting of internal rotation and adduction of the extremity with mild flexion of the thigh, is quite characteristic. There is a short-

it shortens the period of bed rest, allowing weight-bearing much earlier. These two factors are very desirable not only from the standpoint of the patient's health and comfort but are also very conducive to healing of the fracture. In the hands of well-qualified surgeons, the incidence of solid bony union with no complications is about 85 per cent. Early complications are infection, inadequate reduction, and "incorrect pinning." Late complications are "backing out" of the pin, with loss of adequate fixation, and aseptic necrosis of the head.

Several methods of inserting these pins or nails have been described. Regardless of which method is used, reduction must first be obtained. In order to first achieve good reduction, manipulation is carried out, under a local or general anesthetic, by the Leadbetter (24) maneuver, which is an excellent method of correcting the displacement. This maneuver consists of manipulation with the hip and knee flexed and the pelvis fixed; while the leg is in this position, traction is exerted upward on the thigh which is gently rotated internally to engage the fragments. When the reduction is effected, the hip is brought out into extreme abduction with the foot and leg in internal rotation, fixation of the pelvis being maintained by abduction of the other thigh. An efficient reduction is indicated if the heel of the affected leg will remain in the palm of the surgeon in an abducted and internally rotated position (heel-palm test).

One method of internal fixation consists of making an incision one or two inches long over the trochanter, and inserting two or three heavy wires through the trochanter into the head of the femur by means of a drill. A Smith-Petersen nail of proper length is threaded over the wire, which is shown by x-ray to be in the best position, and driven through the trochanter into the head to obtain complete fixation. Some surgeons prefer to drive the nail without the aid of the guide wire, particularly if a protractor is used to guide the direction of the nail. Regardless of the method of nailing used, the x-ray will be of inestimable value in determining whether or not the position is satisfactory. A lateral as well as an anteroposterior x-ray is necessary. These x-rays should be made, developed, and read after reduction and before incision has been made. They should be repeated and read after the internal fixation material is in place and before the wound is closed. After closure of the wound the patient is placed in bed with the affected leg suspended with the aid of a few pounds of traction for about four weeks, after which time he may be allowed up, using crutches for a period of four to six months, permitting only slight weight-bearing at first. The nail need not be removed unless complications develop.

Instead of using a large nail as a means of internal fixation, more recent procedures have employed four smaller pins (Moore) threaded at the end, which engage the head of the femur. Ordinarily, the x-ray will be of value in determining whether or not union is taking place insofar as decalcification with decrease in density takes place in the head of the femur under normal circumstances of healing.

Another modification of internal fixation, using an originally designed incision and flange as reported by Cubbins, Callahan, and Scuderi (25) is very satisfactory. Even though the incision appears extensive, incising the capsule and allowing full view of the fracture line, they report only one death in 105 patients operated upon; union was obtained in 90 per cent of the fresh fractures. The incision has an important advantage insofar as pieces of periosteal synovial membrane, which might lodge between the bone fragments and encourage nonunion, can be seen and removed. The incision has an added advantage in that the extent of reduction by the Leadbetter maneuver can be observed.

If the x-ray shows signs of necrosis of the head, or erosion of the neck of the femur, protection by means of the caliper splint will have to be extended and weight-bearing postponed for several months. The insertion of bone grafts into the area of aseptic necrosis aids in the revascularization of the area, and many aseptic necrotic heads can be salvaged. This is especially important and should be recommended in the younger group of patients (i.e., 60 years of age or younger). Phemister has discussed the features of aseptic bone necrosis in detail. X-ray changes, including increased density of the head, may be the first evidence of necrosis.

As already mentioned, *nonunion* in frac-

tures of the neck of the femur occurs frequently, even when treated in expert hands, although the incidence has been reduced sharply by internal fixation. However, a positive diagnosis of nonunion cannot be made earlier than six months after the injury, even with the aid of the x-ray. Nonunion is suggested in the x-ray by an absorption of bone at the line of fracture, but particularly by a more dense appearance of the head of the femur, or at the fracture line. This apparently paradoxical condition (viz., increased density of the head of the femur associated with nonunion) is due to the fact that normal bones with adequate blood supply always exhibit decalcification following immobilization. The absence of the absorption of calcium, therefore, is indicative of inadequate or absent blood supply.

Five major operative procedures are available in the treatment of nonunion of fracture of the neck of the femur.

1. Internal fixation, using nails or pins as described for the treatment of fresh fractures, may be successful, but obviously in a lower percentage of cases.

2. A bone graft may be inserted through the trochanter into the head, a procedure more difficult than nailing, but perhaps associated with a higher percentage of success.

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Fig. 23. Dislocation of the hip. A, roentgenogram shows an anterior dislocation, with the head of the femur lying in the obturator foramen. The dotted line illustrates the usual position of the head in posterior dislocation of the hip which is more frequent than the anterior type; B, x-ray film after reduction.

ening of the distance between the anterior superior spine and the internal malleolus compared with the uninjured side. The amount of pain produced by the injury is variable, but frequently is surprisingly mild. On many occasions, however, the amount of pain, tenderness, and local findings is so similar to the manifestations encountered in fracture of the hip that a differential diagnosis cannot be made without the aid of an x-ray.

Reduction may be performed in several ways. The Bigelow manipulation as herein described is one of the effective procedures. A general anesthesia should be administered to obtain good relaxation; cyclopropane or intravenous pentothal are satisfactory. The thigh is flexed, adducted, and rotated internally while traction is being made by the operator's arm hooked under the patient's bent knee. This procedure should disengage the head of the femur. The thigh is then abducted, and increased traction made upon the extremity while it is being rotated externally for a posterior dislocation, and internally for an anterior dislocation. Completion of this maneuver usually results in reduction, but if this procedure is ineffective it should be repeated. Opinions differ as to the length of time

that should elapse before weight-bearing is allowed, but walking before 12 or 16 weeks is considered inadvisable by most surgeons. As intimated previously, the greatest danger from the standpoint of complications in convalescent care lies in the possibility of aseptic necrosis of the head of the femur resulting from destruction of the blood supply through the round ligament. Therefore, too early and extensive weight-bearing may give rise to collapse of the head with subsequent permanent lameness (Phemister). The x-ray may be helpful in determining the development of necrosis as noted by increased density, but would rarely be noted under two or three months.

Anterior Dislocation. Injury of this type, with dislocation of the head of the femur through the anterior or lower portion of the capsule so that it rests anteriorly upon the obturator foramen, is usually produced by violent abduction of the hip. The deformity produced is much different than that observed in posterior dislocation. The thigh is abducted and flexed with external rotation. The knee is also flexed. The extremity cannot be extended or adducted while the dislocation exists. Reduction is performed by flexing and abducting the thigh (after administration of an anesthetic) and the use of traction on the extremity. The thigh is then rotated inward and extended. Reduction may be faciliated by having an assistant exert pressure laterally against the proximal part of the thigh.

The Stimson method is not as well known as the Bigelow maneuver but by many is considered easier to perform and less traumatizing to the patient. The patient is anesthetized face down and the dislocated hip is permitted to hang over the side of the cart or operating table. The thigh is flexed to right angle with the spine and the knee at right angle to the thigh. Gentle downward pull is then exerted on the leg, putting maximum pressure in the popliteal area. For a posterior dislocation, the leg is slowly rotated clockwise; for an anterior dislocation, it is rotated counterclockwise. The head can be felt as it rides over the rim of the acetabulum, and a definite "pop" can be felt and heard when the reduction occurs.

The Trochanters. Intertrochanteric fractures are sustained in a manner similar to fractures of the hip, but occur in older people, and are probably associated with more violence and trauma. Although extracapsular fractures rarely lead to nonunion because of the richer blood supply, they are more common and are associated with a slightly higher mortality. The fracture line may extend through both trochanters. The amount of displacement is usually small and separation of fragments is not marked. The clinical manifestations are similar to those of fracture of the hip, except that shortening is not as pronounced. Treatment may be effectively carried out by internal fixation (26), traction with the Thomas or Hodgen splint, plaster cast (Fig. 24), or Anderson's "well-leg" traction splint. In some cases, internal fixation with a Neufelt or Jewett nail will be preferable because they enable the patient to be out of bed much earlier. Frequently, however, the outer fragment is too badly cominuted to give good fixation. Weight-bearing is discouraged until union is quite firm. Ordinarily, firm union will take place several weeks earlier than in intracapsular fractures because of the large surface involved and the increased blood supply; both factors will result in the formation of more callus. If shortening occurs, and it often does, the disability may be minimized by using a shoe with a built-up heel on the affected side.

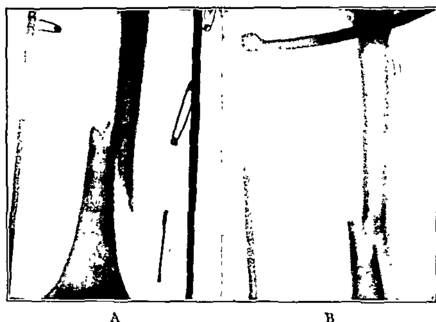
Shaft of the Femur. The type of violence producing a fracture of the shaft of the femur may be either direct or indirect. Shock may be produced by this type of injury and may be as pronounced as in fracture of the neck of the femur. Pain is usually severe and complete disability is present. Because of the depth of the tissue overlying the fracture, tenderness is diffuse; and though considerable swelling is present, ecchymosis is delayed or absent. Measurements between the trochanter and external malleolus reveal a shortening on the injured side unless a fracture exists without displacement. Crepitus will be present, but no attempt should be made to elicit it because of pain and trauma inflicted. Slight and gentle rotary motion of the knee or leg will reveal a failure of the trochanter to move with the shaft. Because of the pain and shock produced by transportation, immobilization should be effected by some type of metal or wood splint *at the scene of the accident* and



Fig. 24. Plaster spica. This cast was applied to a patient with an intratrochanteric fracture but, in general, internal fixation with some type of pin is preferable.

before the patient is transported to the hospital or other suitable place for roentgenograms and treatment. A traction splint, such as the Thomas or Keller, is most effective in preventing and in reducing displacement during transportation. Displacement as well as overriding of fragments is nearly always great, owing to the number and strength of the muscles attached to the femur. The amount and type of displacement depends to a great extent upon the location of the fracture. In fractures of the *upper third* of the shaft, the iliopsoas and glutei muscles tend to abduct and flex the proximal fragment so that it usually lies anterior and lateral to the distal fragment. The deformities of fractures of the *middle third* are apt to be variable, but the proximal fragment usually lies anterior and lateral to the distal fragment as in fractures of the upper third, but with less displacement. The anterior convexity of the thigh is lost. In fractures of the *lower third*, the pull of the gastrocnemius displaces the distal fragment posteriorly. Fractures in this location are occasionally associated with injury to the popliteal artery or nerves; severance of the artery is serious because of the danger of gangrene, but fortunately this is a very rare complication.

Treatment. Simple reduction and immobilization in a plaster cast is not satisfactory, because reduction is difficult to achieve and even more difficult to maintain. Fractures of the shaft are, therefore, usually best treated by suspension and adhesive or skeletal traction. In either case a Thomas splint (Fig. 25) will be found suitable to obtain suspension of the limb. Bending the splint to allow a few degrees flexion at the knee, or the use of the Pierson attachment, will add to the comfort of the patient and to a slight extent encourage the return of motion in the joint. If adhesive traction is used, either a Hodgen or Thomas splint will be found satisfactory. An important feature of the traction lies in the necessity of placing the extremity in a position with sufficient abduction and flexion of the thigh to bring the distal fragment into alignment with the proximal fragment. Moreover, with the thigh flexed, the weight of the body aids in attaining efficient



A B

Fig. 25. Fracture of the shaft of the femur. A, before treatment; B, position of fragments after five days' traction in a Thomas splint. Ultimate result good with only 0.5 inch shortening.

counter traction. If the fracture is oblique, and there is little overriding, adhesive traction should be adequate to obtain satisfactory results. However, if the fracture is transverse (*usually with pronounced overriding*), *reduction* is much more readily obtained by skeletal traction. Skeletal traction can be carried out by the insertion of a Steinmann pin through the upper third of the tibia, immediately posterior to the anterior tibial spine, or through the os calcis, and application of traction to the stirrup attached to the pin. The application of 30 to 40 pounds of traction usually corrects the overriding in two to three days, at which time spontaneous reduction of fragments frequently occurs, but if not, very little manipulation is necessary to bring the fragments into position. Frequent observations by x-ray may be necessary lest overpull result in separation of the fragments. Attempt need not be made to secure perfect end-to-end approximation; if the two fragments are merely locked at the edge, good results may be expected provided alignment and proper immobilization are maintained. After the fragments are locked end on, the amount of traction should be reduced to 10 to 15 pounds. Regardless of the type of traction used, the splint will have to be suspended in some type of overhead (e.g., Balkan) frame (Fig. 26). In many cases, suspension and traction may be replaced by a plaster cast after three to four weeks; at this time there is no danger of losing the position of the fragments.

In fractures of the middle third of the femur the strong plea made by Sofield (27) to use conservatism in the treatment of fractures is quite applicable, although it is admitted that certain circumstances require *radical treatment.*

If the fracture is located in the *upper third,* traction will have to be maintained in wide abduction with considerable flexion of the thigh so that alignment of fragments may be achieved. Usually, *some type of skeletal traction* as previously mentioned will have to be used. Adhesive traction will not be very useful in fractures in this location but will find its greatest usefulness in the fractures in the *middle third,* care being taken that the posteriorly displaced distal fragment is held forward by the flannel or canvas bands or by a sling attached to the frame in traction. Only slight abduction is indicated in fractures of the middle third.

If the fracture is in the *lower third,* the distal fragment will be so firmly displaced posteriorly by the gastrocnemius muscle that adhesive traction will be inadequate in obtaining proper position of fragments. Skeletal

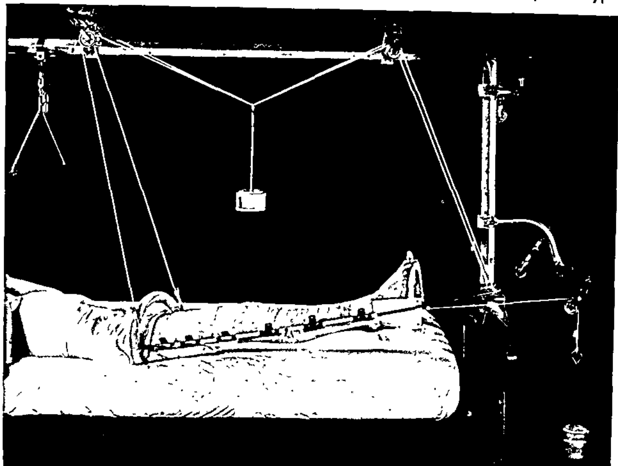


Fig. 26. Buck's extension for traction on the femur. Such traction is useful in fractures of the femur not requiring internal fixation. (After Scuderi, Atlas of Orthopedic Traction Procedures, C. V. Mosby.)

traction is much more efficient, especially because it permits the acute degree of flexion at the knee required to maintain proper position. It may be obtained with a Steinmann pin through the upper end of the tibia. Occasionally it may be wise to reduce the fracture under an anesthetic and apply a plaster spica with the knee flexed. If so, the position of the fragments must be checked frequently by x-ray and the circulation of the leg carefully watched. The pin may be removed in eight weeks and the patient allowed up on crutches with the aid of a walking caliper splint.

The Stader method of fixation of the pins (after placement through the fragments) to a bar external and parallel to the skin is used by some surgeons in order to avoid prolonged hospitalization, but should be used with caution, because such complications as osteomyelitis are relatively common following its careless use in fractures of the femur. Open reduction with internal fixation may be indicated at times, if proper reduction is unobtainable by manipulation alone. In the hands of well-qualified surgeons, open reductions with internal fixation of the fracture should be done early in cases with displacement or soft tissue interposition. Plates and screws are best used in most cases. Transverse or short oblique fractures of the middle third of the femur lend themselves to fixation with a Küntscher rod. This procedure, however, requires a good operative team and adequate equipment.

The *after treatment* of fractures of the shaft of the femur is extremely important. Regardless of the type of traction apparatus used (with the exception, perhaps, of the skeletal fixation method just described), it must be watched daily and adjustments made as indicated. Such precautions include application of pressure over fragments to aid in alignment, watching skin for pressure sores, guarding against knots slipping, use of counter or

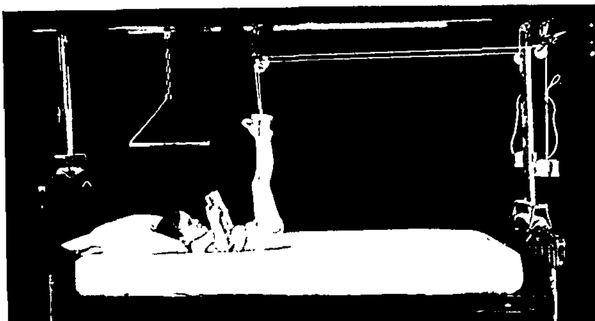


Fig. 27. Bryant's overhead traction for fracture of the femur in children. The injured extremity alone, or both, may be suspended with traction. Sufficient weight is used to barely lift the buttocks off the bed. Suspension and traction of both extremities has the advantage of supplying more stability, although more traction can be obtained if only the injured extremity is suspended. (After Scuderi, Atlas of Orthopedic Traction Procedures, C. V. Mosby.)

secondary traction, and so forth. When traction is chosen as the method of treatment it must be maintained for six to eight weeks, after which time a plaster cast may be applied for an additional six weeks or more depending upon the type of fracture and rate of healing. However, it is usually desirable, eight to twelve weeks after the fracture, when union is fairly solid, to allow the patient up in a convalescent caliper splint which takes the weight off the foot. Actual weight-bearing should not be allowed to any significant degree up to six months following fracture. Active and passive motion as well as massage should be instituted as soon as possible without disturbing the traction and position of fragments.

Compound fractures of the femur are uncommon except in penetrating bullet or shrapnel wounds because of the large amount of muscle surrounding the bone. Usually, the amount of bone projecting beyond the skin is so small that extensive débridement may not be necessary. Traction and immobilization may be carried out as outlined above. If skeletal traction is used, the wire or pin must not be inserted through the bone near the fracture line because of the danger of osteomyelitis.

Fractures of the Shaft of the Femur in Children. Most fractures of the femur sustained by children are located in the shaft. Up to the age of five or six years they are best treated by Bryant's overhead suspension and traction (Fig. 27). Adhesive is applied up to the level of the fracture, the extremity is then suspended upward at right angle to the bed, and sufficient traction applied to just raise the buttocks from the bed. Immobilization in traction for four weeks followed by fixation in a plaster spica for four or five more weeks usually is sufficient immobilization to begin weight-bearing.

For children over six years of age the Russell traction, consisting of adhesive traction from the knee down with flexion of the knee created by a sling, will be found very useful. This mechanism can often be used advantageously in adults, particularly when a maximum amount of traction is not needed. Its great advantages are simplicity and freedom of movement by the patient. One disadvantage is that it requires constant care and adjustment.

The Knee. FRACTURE THROUGH THE FEMORAL CONDYLES. This fracture may be inflicted when violence of unusual degree is sustained by a fall upon the feet or knees. The condyles are usually split in a T fashion so that the fracture extends into the joint; commonly the fragments are displaced posteriorly and spread apart. Such a fracture is serious because of the difficulty in obtaining adequate reduction and in preventing stiffness or ankylosis of the knee. Skeletal traction, obtained by a Kirschner wire inserted through the tubercle of the tibia, is usually the treatment of choice because in this way sufficient flexion of the knee may be secured to relax the pull of the gastrocnemius. Frequently, operative reduction with some type of fixation of fragments will be indicated or necessary. Closed reduction by instrumental manipulation will often be indicated and successful, although difficulty will usually be experienced in maintaining reduction.

Unless the articulation of the joint is restored to normal, a severe arthritis will rapidly result. For this reason, accuracy of reduction is imperative. If this is not obtained by closed reduction, open reduction with internal rotation should be resorted to. Long screws or a right-angle blade plate can be used advantageously in many of these cases.

SEPARATION OF THE LOWER EPIPHYSIS OF THE FEMUR IN CHILDREN. This injury is encountered as a result of violent trauma, such as a bad automobile accident. The distal fragment is displaced anteriorly. Reduction should be carried out under anesthesia and is usually accomplished with ease. The extremity is immobilized in a plaster cast with the knee flexed. An open reduction should not be done because of the danger of nongrowth unless adequate reduction is not obtained by the closed method.

FRACTURE OF THE PATELLA. This is a common injury and is usually sustained by a direct blow over the knee. Effusion into the joint is usually profuse and contains a large amount of blood. The patella may be comminuted with or without displacement, but the fracture is usually transverse. When complete, the lateral tendinous attachments of the joint ligaments are usually torn and wide separation of the fragments is produced. In such cases, operative reduction is adopted (Fig. 28) unless sufficient injury has been in-



Fig. 28. Fracture of the patella. Left, wide separation and pronounced hemarthrosis due to intra-articular bleeding is noted. Operative reduction is necessary. At this time the soft tissue tear in the retinaculum must likewise be carefully reapposed and sutured. Right, postoperative films show anatomic reapposition of the patellar fragments, held in place by a loop of wire.

flicted to the skin about the patella to jeopardize asepsis, a complication which commonly occurs. The danger of infection in such a situation may be so great that it will be necessary to delay operation for many days until the skin has healed. Adequate fixation of the fragments by open operation allows early motion, thereby tending to prevent stiffness of the knee, which is a frequent complication of fractures of the patella. Fixation of bone is usually accomplished by wire sutures. Occasionally, the patella will have to be removed if the comminution is severe. Wire sutures through small drill holes in the anterior surface of the patella are very effective; the solidity of the repair obtained by metal sutures allows early motion and is, therefore, very advantageous in fractures about the knee. The tear in the capsule and quadriceps aponeurosis *must* be repaired. Fixation of fragments must be so secure as to allow active motion in a few days and weight-bearing in two or three weeks. If no separation of fragments exists, simple fixation of the knee by a thin plaster cast will be the method of choice. Excision of small distal fragments and suture of the patellar tendon to the proximal fragment is sometimes used.

Dislocation of the Patella. This is uncommon and usually occurs in childhood, but tends to recur with only slight violence. The patella is dislocated outward. It may occur in adults, particularly women, when falling upon the knee with force exerted outward on the patella. Reduction is easily effected and usually without an anesthetic. In recurrent dislocation, operative repair may be indicated.

Dislocation of the Knee. This is a rare injury and is sustained only by severe violence. Injury to the peroneal nerve or popliteal vessels is frequently sustained simultaneously. The dislocation may be one of three types, i.e., with the head of the tibia displaced anterior, posterior, or lateral to the femur. The collateral and cruciate ligaments are usually torn, thus allowing remarkable mobility. The anterior type of dislocation is the most common and is usually produced by hyperextension. Reduction is easy, but fixation must be maintained in a plaster cast for five or six weeks to prevent a relaxed joint which is so apt to follow such injuries: therefore, open operation with repair of the ligaments at time of injury is frequently advisable.

Rupture of Cruciate Ligaments. Rupture of the cruciate ligaments is fortunately not common but such minor injuries as stretching and tearing are no doubt sustained in many sprains and fractures about the knee, particularly when the knee is overextended and rotated. Unusual mobility of the knee, particularly in the anteroposterior direction, is the most diagnostic sign. If the anterior cruciate ligament is torn, the mobility is apt to be most prominent when the knee is extended. When the posterior cruciate is torn the mobility will be most marked when the knee is flexed. For treatment of torn cruciate ligaments, immobilization of the knee in a plaster cast for about six weeks is probably the method of choice. Operative repair of neglected cases is recommended by some surgeons and may be facilitated by the use of fascial strips.

Injury to the Semilunar Cartilages of the Knee. The semilunar cartilages are flat, circular structures which are attached by their ends near the center of the joint and furnish a concavity for articulation of the condyles of the femur. Their lateral attachments to the capsule and lateral ligaments are so insecure that detachment or injury at this point is frequent. The medial cartilage is injured much more frequently than the lateral. The injury may consist of a detachment, tear, or a crush and is usually sustained by sudden extension of the joint with twisting. Considerable pain is usually experienced at the time of the initial injury. If a piece of cartilage is torn off or displaced there may be "locking" of the joint with inability to completely extend it. Tenderness is usually present along the articular surface of the tibia on the medial side. Commonly, reduction occurs spontaneously, in which case the characteristic "locking" will be absent. Diagnosis may then be difficult and can be made on the basis of recurrent attacks of pain in the knee without x-ray changes. Acute injury of the cartilage is usually associated with an accumulation of fluid which may be bloody or serous in type. Many surgeons strongly recommend aspiration for practically all types of effusion following trauma (Shands) on the basis that

bloody fluid, if not removed, encourages the development of adhesions.

Once a semilunar cartilage has been torn and has produced locking, surgical removal is indicated, as the cartilage will not heal because of absent blood supply; moreover, recurrences are inevitable. Surgery can be performed at the convenience of the patient unless the locked knee cannot be unlocked by manipulation, in which case there should not be too much delay (several days).

SPRAIN OF THE KNEE. Injuries of this type are common and consist primarily of a stretching or tearing of the lateral ligaments which are, in reality, thickened portions of the capsule of the joint. Fluid commonly accumulates within the joint so that the patella is floating and the normal joint landmarks are obliterated (acute traumatic synovitis). Ecchymosis may be present. Flexion of the joint is painful, but unless the semilunars are likewise injured, extension is free and painless. Lateral mobility of the knee may be increased because of the tearing or stretching of the ligaments. The internal lateral ligament is most often affected. It is particularly important to get an x-ray of the joint if disability is very pronounced because a sprain fracture (i.e., avulsion of a small fragment of bone at the attachment of the ligament) is so often present.

Treatment consists of rest of the affected part for two or three weeks, depending upon the severity of the sprain. In severe cases it may be necessary to resort to immobilization with a plaster cast or similar type of fixation. The joint should be aspirated if fluid is present.

The Tibia. Under this heading will be included fracture of the upper end of the tibia and fracture of the shafts of the tibia and fibula.

UPPER END OF THE TIBIA. Fractures may be sustained through either or both condyles of the tibia. They are commonly due to direct violence when the patient is struck by the front bumpers of an automobile; on such occasions they are called "bumper fractures." The fracture line in the "high bumper fractures" almost invariably extends into the joint. If the fragment includes the condyle or a small portion thereof, it is usually displaced downward. There is nearly always a concomitant injury to the cartilage and occasionally of the peroneal nerve with foot drop. Pain is unusually severe. The joint is filled with fluid, the greater part of which is blood. It is particularly important to obtain as complete reduction as possible, because of the danger of development of a permanently painful joint. Furthermore, if the condyle is not replaced upward into its normal position, genu valgum or genu varum is apt to develop, depending upon which condyle is displaced. Traction will usually be the most adaptable method of treatment. Reduction of fragments by direct manipulation is difficult, but may be facilitated by the application of a clamp over the fracture site to compress the fragments into position. Frequently reduction will not be possible by traction and manipulation, making it necessary to resort to operative reduction. On account of the active blood supply in this region, union takes place rapidly, but weight-bearing should not be allowed for 12 to 18 weeks because of the tendency for the soft callus to give way, with a resultant knock knee or bowleg deformity. "Bumper fractures" now occur lower down on the leg because cars are made with lower bumpers. Frequently, therefore, they do not involve the joint.

SHAFTS OF THE TIBIA AND FIBULA. Fractures of the shafts of the tibia and fibula may occur at any level, but are most frequent at the junction of the lower and middle thirds where nonunion is also most common. The fractures may be transverse, oblique, or spiral, with or without comminution. The lower fragment of the tibia is usually displaced posteriorly. The fractures may be caused either by direct or indirect violence. In the former case, as when the direct blow is sustained, the fracture in the two bones is apt to be at the same level. In indirect violence, the tibia usually breaks near the junction of the middle and lower thirds, and the fibula at a higher level. For that reason it is particularly important that the x-ray include the entire leg from the ankle to the knee. Diagnosis of a fracture of the tibia is usually made without difficulty because the bone is subcutaneous over its entire anterior surface. The patient is unable to walk unless the fracture is impacted or incomplete. Pain and local tenderness point to the location of the frac-

ture. Swelling and ecchymosis develop after a few hours. When the fracture affects only the upper two thirds of the fibula, the manifestations will be less severe; the patient may be able to walk with only a moderate amount of difficulty, since the fibula has little to do with weight-bearing of the body.

TREATMENT. There are several anatomic features which must be borne in mind during the treatment of a fracture of the tibia. For example, the articulation at the ankle and knee must be restored to the normal position; otherwise a painful joint with disability may result. It is essential then that proper alignment be obtained in the anteroposterior, as well as the lateral, plane (28). A mild degree of shortening is tolerated without detriment to the patient as far as function is concerned. However, a posterior bowing (i.e., convexity posteriorly) is particularly disabling and for that reason it may be wise to overcorrect this deformity at the time of reduction by producing a mild anterior angulation. Usually the fragments can be reduced manually without difficulty and molded into position with the patient under proper anesthesia. Flexion of the knee frequently facilitates reduction. If reduction is obtained, it is obviously important to maintain position of the fragments while the cast is being applied. Care must likewise be taken to avoid medial and posterior bowing. The foot is placed at right angles to the leg and in mild inversion. If the fibula alone is fractured, immobilization in a cast for six weeks should be sufficient to permit painless weight-bearing. However, if the tibia is fractured, immobilization in a cast must be maintained for at least 10 to 12 weeks. Following this, the patient is allowed to walk with crutches, weight-bearing being permissible and encouraged, particularly if a walking iron has been incorporated into the cast (Fig. 29).

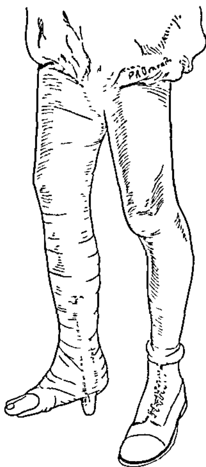


Fig. 29. Skin (unpadded) cast with metal foot piece incorporated in the cast. This is particularly useful in patients with delayed union of the tibia and fibula. The skin cast is often used as a primary form of treatment; its fixation is more secure and it permits ambulatory care.

Occasionally, and particularly when both bones are fractured or the tibial fracture is an oblique one, correct apposition of fragments cannot be maintained adequately by simple reduction and the application of a plaster cast. In such instances, it may be advisable to insert a Kirschner wire through or above the os calcis and secure constant traction to the stirrup connected with the wire (Fig. 30). Traction by this means encourages correct alignment and maintains a correct position for the foot and ankle. The alternative method is to insert a Kirschner wire through the lower fragment as well as the upper fragment, to reduce the fracture by manipulation under anesthesia, and then to incorporate the pins into the cast applied from the toes to mid-thigh while traction and reduction are being maintained (Fig. 31). Primary open reduction with internal fixation is recommended by some surgeons, especially when the tibial fracture is oblique in type.

Delayed union or nonunion is fairly common in fractures at the junction of the middle and lower thirds, partly because of deficient blood supply, but particularly because the lack of muscular attachment allows dissipation of the clot. Accurate reduction lessens

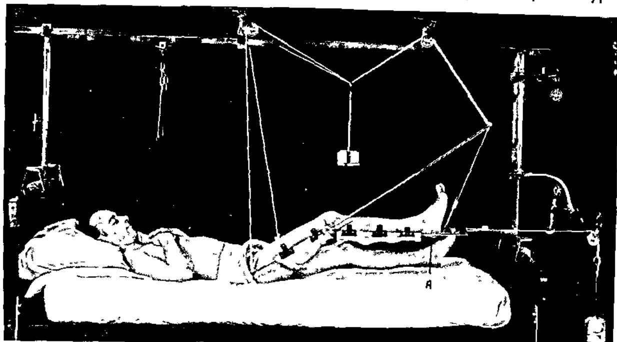


Fig 30. Thomas splint and Pearson attachment. This apparatus with a Steinmann pin through the os calcis at point A is commonly used for "both bone" fractures of the tibia and fibula with severe overriding and comminution. (After Scuderi, Atlas of Orthopedic Traction Procedures, C. V. Mosby.)

A B C D

Fig. 31. *Fracture at the distal third of the tibia and fibula. A and B reveal marked* communication as well as moderate angulation and overriding. To obtain good reduction and proper immobilization, double pin fixation was indicated. *C and D, one pin was placed through the os calcis and the other* through the upper third of the tibia. A boot cast was then applied from the base of the toes to the knee, with the foot at right angle to the tibia.

the possibility of nonunion. If, after six to eight weeks of immobilization, there is no evidence of union, the deposition of callus may frequently be encouraged or hastened by allowing the patient to bear weight on the foot, providing, of course, a close-fitting plaster cast (skin cast) from the toes to the midthigh maintains position and alignment (see Fig. 29). This method may also be used as the primary procedure when displacement is not marked. Griswold (29) has emphasized the value of the ambulatory treatment with a nonpadded cast and walking iron, in fractures of the tibia and fibula, in the prevention of bone atrophy and nonunion. Although weight-bearing in a walking cast is permissible in six weeks, weight-bearing without support should not be allowed for four months. Bone grafts are often effective in nonunion (30), and at times are advisable.

Open (compound) fractures occur more often in the tibia than in any other bone, chiefly because the tibia is subcutaneous over such an extensive area. If the break in the skin is small and there is reason to suspect that very little and unimportant contamination has taken place, the fracture may be treated as a simple fracture with reduction and application of a plaster cast or splint as indicated after the area has been mechanically cleansed and closed. However, if much bone has protruded, or if the wound is large and obviously seriously contaminated, thorough débridement must be done immediately unless contraindicated by serious injury elsewhere. Extreme care must be taken in the removal of foreign bodies, dead tissue, blood clots, and small fragments of bone. After the fragments are reduced, the wound including the skin is closed. Rarely is a drain justified. Immobilization is then obtained by a plaster cast, skeletal traction, or double pin fixation, as indicated. If a cast is used, a window may be cut in it at the site of the fracture so that the wound may be inspected, but only if fever or undue pain develops. If the injury is more than seven or eight hours old, but with no evidence of infection, débridement should still be carried out. In serious cases, continuous traction with metal pins and some type of frame may be indicated (see also p. 463). Most surgeons do not recommend prophylactic use of antibiotics, but if infection develops, antibiotics are indicated; a culture should be obtained and sensitization tests carried out so that the most effective antibiotic can be utilized. If infection is significant, the wound should be opened for drainage.

The Ankle. Because of the relatively small size of the structures existing in articulations at the ankle and the great weight of the body, injuries in this region are common and usually produced by indirect violence. As will be discussed later in the text, injuries involving the joints (particularly of the tarsal bones) are most serious, since permanent dysfunction due to pain is apt to develop; position of fragments becomes very important in such injuries.

POTT'S FRACTURE. Percivall Pott, in 1768, in his "Remarks upon Fractures and Dislocations" described an uncommon fracture which originally bore his name. It is a fracture of the fibula, two to three inches above the external malleolus, produced by eversion and associated with the tearing of the internal, external, or deltoid ligament extending from the astragalus and os calcis to the internal malleolus. Occasionally, only a small flake of bone is avulsed from the internal malleolus while the deltoid ligament remains intact. There is an associated lateral subluxation of the astragalus. However, over the years the term "Pott's fracture" has been loosely used to describe any fracture of the ankle involving any or all malleoli. This common usage has completely supplanted Pott's original description of the fracture which almost 200 years ago first bore his name.

The most common type of Pott's fracture consists of a fracture of the fibula one or two inches above the ankle and an avulsion of the tip of the internal malleolus. Such fractures are produced by a variety of forces including inversion, eversion, hyperflexion, hyperextension, rotation, and perhaps an additional factor of compression of the foot against the leg. Often several of these factors act together. The primary lesion resulting from such injury is a displacement of the astragalus on the tibia. Since the two malleoli are firmly attached to the astragalus by strong ligaments, displacement of the astragalus may carry adjacent fragments with it. Occasionally, the fracture extends through the entire shaft of the tibia as well as fibula a few centi-

meters above the joint. This usually occurs, however, only when the trauma is severe. If the foot is also forcibly extended (i.e., in plantar flexion) during the injury, a posterior fragment of the tibia may break off, including a considerable portion of that bone, giving rise to what is now called a trimalleolar fracture, which years ago also bore the name "Cotton fracture," after Frederick Cotton of Boston who contributed much to the description and treatment of this fracture. Although the ligamentous attachment between the lower portions of the tibia and fibula is strong, there is a tendency toward tearing or stretching of this ligament with separation of the two bones and a mild lateral displacement of the astragalus. One type of deformity of extreme importance in Pott's fracture is a posterior dislocation of the astragalus, at the tibial articulation. This is particularly apt to occur if the injury is produced by forcible extension of the foot. Less commonly, a Pott's fracture is sustained by forcible adduction or inversion of the foot. In this case, the external malleolus is pulled away and the internal malleolus is broken by infringement of the astragalus. Occasionally, the entire shaft of the tibia is broken.

The clinical manifestations of Pott's fracture are extremely variable. The cardinal signs of fracture (as described on p. 457) may be present, but if the fracture is limited to the fibula and not complete or displaced, the patient may be able to walk with only moderate difficulty (Fig. 32). Local tenderness will, of course, be present over the external malleolus and perhaps over the lower border of the internal malleolus. However, there may be no way of differentiating this type of a fracture from a sprain without the aid of an x-ray, which should always be taken in such instances. There may be an obvious eversion or inversion deformity, depending upon the mechanism of fracture. If the fracture includes the shaft of the tibia, the patient will, of course, be unable to bear any weight whatever upon his foot, unless impaction exists. The backward dislocation of the astragalus may not be demonstrable, although the foot is almost always held in a position of extension (i.e., plantar flexion). Part of the swelling about the ankle is accounted for by the bloody effusion into the joint which is somewhat greater than expected. The swelling tends to mask deformity and obliterate the bony landmarks.



Fig. 32. Fracture of lower end of the fibula. The external malleolus is fractured but very little displacement is present. There is no visible fracture of the tip of the internal malleolus, but the ligament may be torn. The leg should be put in a cast for four or five weeks with the foot in inversion.

The *treatment* of most patients with Pott's fracture is simple, chiefly because reduction is rarely difficult. If the fragments of the fibula buckle inward toward the tibia, or if a chip of the internal malleolus is displaced downward, or if fracture of the tibia with displacement exists, reduction under anesthesia will be necessary. Much better results are obtained if reduction is performed as soon as possible after the accident and not delayed until after the swelling becomes minimal, as was practiced by many surgeons years ago. Proper reduction consists primarily of *inversion of the foot, traction, and flexion of* the foot to a right angle with the shaft of the tibia, and the application of a cast as mentioned above. It is important that an x-ray be taken after reduction to be sure that no deformity remains. Attention is directed particularly to posterior displacement of the astragalus because this type of deformity is frequently overlooked. The simple procedure of placing the foot in a right-angled position tends to correct most of this deformity. Application of a plaster cast from the toes to the knee is the most desirable type of fixation; in fractures with marked displacement, the knee, too, must be immobilized. Fracture of the posterior lip of the tibial articular surface is not uncommon and requires special precautions for an anatomic reapposition of the fragment. Any displacement produces an irregularity of the joint surface with a resulting swollen, painful joint and probable ultimate surgical ankylosis. For this reason, if more than 25 per cent of the joint surface is broken off, careful surgical reapposition is essential, with screw fixation (Fig. 33). The surgical anatomy and technic has been described by *Scuderi and Schrey in 1948. Immobilization* of the fracture is necessary for eight to ten weeks followed by physical therapy, but no weight-bearing under four months.

The toes must be watched carefully for numbness, tingling, coldness, paralysis, and so forth, because any great increase in swelling could easily interfere with the blood supply to such an extent as to jeopardize the structures distal to the obstruction. Since immobilization and proper reduction will practically always relieve the pain of a fracture within a few hours, subsequent development

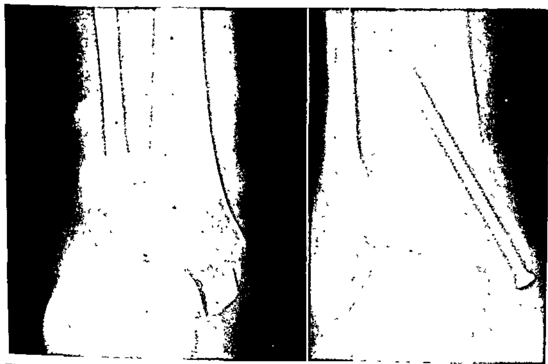


Fig. 33. Bimalleolar fracture of the ankle. Left, the astragalus is subluxated laterally and the medial malleolus has completely lost its buttress function. Unless the ankle mortice is anatomically replaced, a painful ankle will result from a traumatic arthritis. Right, fixation with a screw was chosen here as the method of treatment, but is not necessary in the majority of bimalleolar fractures.



Fig. 34. Compound (open) dislocation of the ankle before and after reduction. Healing occurred without infection and the functional result was good. (St. Louis City Hospital.)

of pain of more than a slight degree may warrant splitting or bivalving of the cast, thereby allowing room for excessive swelling.

If the fracture involves only the external malleolus (i.e., the fibula), the cast may be removed in five to six weeks, the ankle strapped and bandaged, and weight-bearing allowed with crutches. If the shaft of the tibia is fractured, the immobilization should be maintained for eight to ten weeks. Weight-bearing with the aid of crutches should be started cautiously. The application of heat by baking, and the like, will frequently be efficacious in relieving the stiffness and chronic pain so frequently complained of in fractures about the ankle. Such measures will also tend to shorten the period of disability.

DISLOCATION OF THE ANKLE. Posterior dislocation and a mild lateral dislocation may occur in Pott's fracture, as already described. On rare occasions complete dislocation, usually posterior or lateral, may occur without fracture (Fig. 34). Complete dislocation is usually accompanied by fracture of the external malleolus or tip of the tibia, perhaps by both. Reduction of the dislocation is not difficult, but if there is much comminution of the tibia and fibula, considerable difficulty may be experienced in replacing these fragments. Immobilization must be maintained for four weeks, at least. If there has been an accompanying fracture of the entire shaft of the tibia, immobilization for a longer time will be required.

On rare occasions a dislocation of the ankle is *compound*. Treatment is not different from that of a compound fracture. As soon as possible, the wound is subjected to thorough débridement and irrigation, followed by reduction of the dislocation and closure of the wound. Immobilization is best obtained by a plaster cast, but the wound must be observed closely for the possible development of an infection, which, if serious, may lead to gangrene and amputation.

SPRAIN OF THE ANKLE. This injury is almost invariably sustained by forceful plantar flexion and inversion of the foot beyond normal range of motion and is commonly inflicted by throwing the weight of the body on the "turned" ankle, usually after catching the heel on a stair or stepping in a hole while running. The injury consists primarily of a tearing of the external lateral ligaments and is thus produced by a force opposite to that producing a typical Pott's fracture. If the external lateral ligament resists tearing, the tip of the external malleolus may be torn off, constituting what is called a sprain fracture.

The pain inflicted by a severe sprain may be as severe as that produced by a fracture and may be so disabling as to entirely prevent walking. Usually, however, the pain produced by a sprain decreases within a day or two to the extent that at least a slight amount of weight-bearing is possible. Forcible pressure against the heel does not produce appreciable pain when a sprain is present but is quite painful when there is an associated fracture of consequence. Swelling of soft parts about

: injured ligaments occurs within a few ours and a variable amount of ecchymosis ll develop. This ecchymosis is usually less tensive than that associated with a fracture. ne joint not infrequently fills with fluid or ood, but this is usually indicative of injury the joint structures. The *tenderness asso- ated with a sprain is apt to be diffuse* over e injured external lateral ligaments, in con- ast to the local tenderness associated with fracture. Such signs of fracture as crepitus, normal mobility, and deformity obviously ill be absent. The disability sustained by a rain is usually not as severe as that asso- ated with a fracture, particularly in regard weight-bearing. On a few occasions, how- 'er, a badly sprained ankle will produce a ainful joint for many weeks or months in ontrast to the relatively short duration of ain after a fracture confined to a minor bone. he reasons for this difference are not always ear.

The type of *treatment* is variable, depend- ig upon the severity of the injury. If the pa- ent is seen immediately after injury, the ap- lication of cold packs for an hour or two ombined with complete rest of the part may ssen the amount of hemorrhage and exuda- on of serum. The most important feature, owever, is immobilization of the joint. Strap- ing with adhesive in an overlapped fashion ntil the entire joint and lower third of the g are encased in an adhesive splint is usu- lly quite efficient. A nonadhesive elastic ace) bandage or elastic adhesive (elasto- last) is comfortable and effective. This im- nobilization should be carried out with the oot in the position of right-angled flexion and version so as to afford rest for the external ateral ligament which is usually the ligament orn in a sprained ankle. If the internal liga- nents are torn, as happens only occasionally, he foot should be immobilized in inversion. After two or three days' rest, the patient may begin to walk about, using a cane or a crutch as indicated. The application of heat for 30 to 45 minutes, two or three times a day, en- courages hyperemia and is efficient in reliev- ing the pain and promoting healing. The pa- tient should not be encouraged to increase the activity of the joint beyond the production of pain, especially during the first 10 days when healing is taking place. The adhesive splint usually becomes loose after four or five days and must be reapplied. It should be worn as long as pain is experienced during walking and as long as it affords appreciable relief. When the sprain is severe, immobilization with an adhesive splint will not relieve the pain and it will be obvious within 24 hours that more secure fixation is necessary. In this case, the application of a light plaster boot for a week or even more will not only de- crease the pain but will promote healing and allow the patient to walk comfortably with the aid of crutches. After the plaster cast is removed (seven to ten days) the ankle is strapped and the patient allowed to walk more and more each day, depending upon the amount of disability. Obviously the treatment of a sprain should not be undertaken without thoroughly excluding fractures, particularly by x-ray.

One must never lose sight of the fact that a true sprain results in tearing or disruption of the continuity of an important ligament. Healing of ligaments is slow compared to other tissues because of their meager blood supply, and unless healing is complete, a permanently insufficient stability results which leads to recurrence of the original symptomatology.

The injection of novacaine (recommended by some surgeons) abolishes pain and leads to a false sense of security. As it exerts no beneficial effect on the healing of the torn ligaments (and may actually lead to added trauma) it should be used in only the most minor cases.

The Foot. FRACTURES OF TARSAL BONES. These injuries may be very disabling, and consequently require utmost care in treat- ment. Fractures of the tarsal bones include chiefly the astragalus, os calcis, and scaphoid; they are usually sustained by a fall in which the foot receives the impact. The type of frac- ture varies from a single line to a comminu- tion or crushing. The manifestations are so atypical that an accurate diagnosis can rarely be made without an x-ray. Tenderness may be diffuse, as is also ecchymosis and swelling. Walking is very painful, if possible at all. Treatment consists of molding of the frag- ments into position, if possible, and immobi- lization in a plaster cast for four weeks or more. All fractures of the tarsal bones are

serious because of the frequency of permanent disability, due to pain. This is particularly true of fractures of the *astragalus* (*talus*), which are so often followed by persistent pain that many surgeons advise arthrodesis (to produce ankylosis) as the primary treatment immediately after the injury. Occasionally fusion of the ankle and subastragaloid joint is necessary in cases where inadequate reduction or a nonunion has resulted. This permits the patient to have a painless and stable joint. Astragalectomy has fallen into disrepute as fusion is an infinitely better solution to the problem. Fractures of tarsal bones are common in the naval personnel during wartime, being sustained when a torpedo explodes below decks (see Ch. 42).

Fracture of the *os calcis* is apt to be sustained in such a way that flattening of the arch results. It is a frequent injury most common in roofers and painters who fall from a height, striking on their heels. This is an extremely disabling fracture and should be corrected as completely as possible. The flattening of the foot is due to force transmitted to the calcaneus by the wedge-shaped portion of the talus. The calcaneus is crushed and spread laterally, the lateral fragment or fragments coming to rest beneath the lateral malleolus and compressing the structures which pass behind and beneath the malleolus. Marked comminution is a rule, with fracture lines running into and distorting the astragulocalcaneal joint. The posterior portion of the os calcis is forced upward and held by the Achilles tendon. Böhler has laid great stress upon the tuberosity-joint angle, otherwise known as the salient angle. This is the angle between a line drawn from the upper part of the tuberosity of the calcaneus to the highest point of the bone and another from the anterior angle to the highest point. These two lines normally make an angle open posteriorly of 20 to 40 degrees. Following flattening of the bone in fractures, this angle becomes zero or even negative. Böhler regards restoration of this angle as of primary importance in treatment. Reduction of the fracture requires strong traction by a pin or wire through the upper portion of the os calcis, combined with pressure on both sides to reduce the spreading of the impingement of fragments upon the structures below and behind the lateral malleolus. Traction or skeletal fixation in plaster should be maintained for at least 8 to 10 weeks in minor cases, and 14 to 16 weeks in the more severe cases, after which weight-bearing in a skintight cast is permissible. Neglected or unsuccessfully treated fractures may require operative removal of bone from beneath the lateral malleolus and fusion of the astragulocalcaneal joint to reduce the disability from traumatic arthritis.

In general, results are poor, particularly when comminution and displacement of fragments exist; in such cases, healing without at least a certain degree of disability (especially pain) is rarely achieved (Dickson and Diveley, 31). There is much disagreement (32, 33) as to whether conservatism or operative procedures are advisable in fractures of the os calcis but, in general, the former is distinctly preferable.

Dislocation of the Tarsal Bones. A dislocation of the tarsal bones may occur, but is uncommon. The astragalus is the bone most often affected. If a severe blow is sustained on the ball of the heel while the foot is plantar flexed, the astragalus may be thrust completely out of position. So much difficulty may be experienced in exerting enough traction on the foot to allow for replacement of the bone that section of the Achilles tendon may be necessary.

Fractures of the Metatarsal Bones. Fractures of these bones are not infrequent, but dislocation is extremely uncommon because the metatarsals articulate with the tarsals at different levels (Fig. 35). Any one of the metatarsals (perhaps most commonly the first and fifth) may be fractured at any point in its shaft. The distal end of the bone is apt to be displaced anteriorly. Walking is rarely possible on account of pain. Swelling and ecchymosis may be mild. Displacement of fragments can and should be corrected by manipulation under anesthesia. Immobilization by a plaster cast extending to the upper third of the leg is usually the most logical treatment, although occasionally adhesive strapping will offer sufficient immobilization. Weight-bearing without the cast should not be allowed for six weeks. Nonunion and persistent pain are uncommon. "March" fracture, which involves the metatarsal bones and is

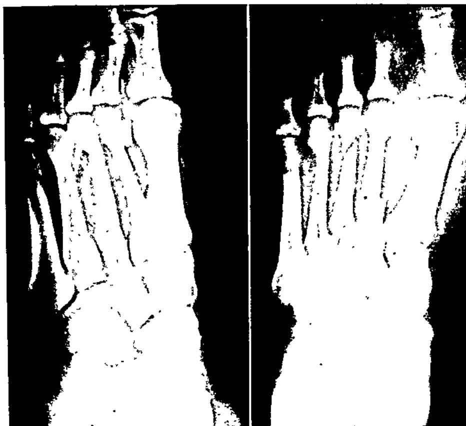


Fig. 35. Fracture of the metatarsal bones. Four bones are fractured, two in two places. Two views reveal very little displacement. Immobilization in a plaster boot is the preferred method of treatment, but in this patient weight-bearing should not be permitted for 8 to 10 weeks.

sustained so commonly during military training, is discussed in Chapter 42.

FRACTURES AND DISLOCATIONS OF THE PHALANGES. Fractures of the phalanges of the toes are common. The distal phalanges of the first and fifth toes are the ones most commonly affected. The injury may be of a crushing type, but more often the patient gives a history of having stubbed his toe in the dark. The pain experienced at the time of injury is usually severe. Local tenderness is pronounced; pressure against the end of the toe is invariably extremely painful. Ecchymosis almost always develops after a few hours. The treatment is unsatisfactory, considering the fact that the injury is so trivial. For fractures other than those in the great toe, an attempt may be made to immobilize the fracture against the uninjured toe. However, if this fixation is inadequate to relieve pain, as it commonly is, it may be preferable to apply a plaster cast with the tip of the cast extending past the end of the toes. For fractures in the great toe, a plaster cast is almost always indicated. The cast may be removed in two or three weeks.

Fractures of the phalanges of the second, third, fourth, and fifth toes are of little clinical significance in walking since displacements and nonunions do not lead to any noticeable disability. However, fractures of the phalanges of the large toe are of considerable clinical importance because of the important role it plays in walking. It is the propulsion power of the large toe that gives human beings the spring in their walking, and it is the flexion power of the large toe that permits walking up inclines without difficulty. For this reason, anatomic reduction and fixation is most essential, and open reduction with pin fixation is indicated in some cases. Irregularity of the metatarsal phalangeal joint must be overcome, otherwise a disabling traumatic arthritis may result.

Dislocations of the phalanges are usually confined to the great toe and consist of dorsal

dislocation at the metatarsophalangeal joint. They are readily reduced by sharp flexion and simultaneous pressure downward at the base of the first phalanx until it slips over the head of the metatarsal. If the flexor tendon has slipped in between the metatarsal head and the phalanx, reduction may be impossible and open reduction required.

THE SPINE AND RIBS

Fractures of the vertebral column may be divided into those of the dorsolumbar region and those of the cervical region. The sacrum and coccyx are discussed under the pelvis.

Dorsolumbar Spine. Of the twelve dorsal and five lumbar vertebrae, the most important ones are those of the lower dorsal and lumbar region, since these are the most movable. The upper dorsal vertebrae are held rigidly by the ribs and are less subject to injury.

COMPRESSION FRACTURE. The most common site of fracture is the body of the vertebra, which is crushed or compressed, hence the frequent use of the term compression fracture. The injury is caused by forced flexion or force applied to the spine while flexed and is often due to a fall with the weight of the body striking the buttocks or feet or a heavy weight falling on the stooped shoulders. In many cases, however, the degree of force is apparently slight. Dislocation of dorsolumbar vertebrae is rare except in severe injuries. Injury to the spinal cord is also encountered only in the more serious fractures and is discussed in Chapter 27. Occasionally associated with spine injuries are abdominal symptoms, which simulate general peritonitis (e.g., distention, vomiting, and abdominal rigidity). If intraabdominal injury is excluded, these manifestations are due to reflex ileus or to retroperitoneal hemorrhage.

The *clinical manifestations* of a compression fracture may be so slight that the lesion is overlooked. Spine injury should be suspected whenever the patient has fallen so that the body weight has been transmitted to the spine, or when force has been applied which might have flexed the spine acutely, such as overturning in an automobile. Deformity may be absent. Local tenderness at the level of the injury and pain on movement may be the only signs. If unrecognized, these fractures may heal spontaneously and result in persistent back pain. An x-ray should be obtained, particularly in the lateral view, in order to demonstrate a compression fracture (Fig. 36). It should be emphasized that the designation of back sprain, which is often applied to many of these injuries, should not be made unless adequate x-ray study has failed to reveal an injury to bone.

The important feature of *treatment* consists of prolonged immobilization in a hyperextended position so that solid bone will be deposited without altering the alignment of the vertebrae. This will prevent further injury to the cord and will even relieve such pressure as may already be present, by restoring the fracture to more nearly normal position. In general, transporting a patient with a spinal injury in the position in which he is found will be a safe policy to adopt. However, hyperextension is easily achieved face down with the vertebral column bowed into extreme lordosis or, if he is being carried supine, a large blanket roll must be placed under the small of the back to achieve the same effect. If a flexion deformity (kyphosis or dorsal angulation) is already present, reduction by forceful or gradual hyperextension of the spine is first carried out. In the former case an anesthetic will be necessary; in the latter method an adjustable type of angulated Bradford frame will be required. If no deformity is present, the patient is placed prone (face down) over a canvas strip and a plaster body cast applied in the hyperextended position. In such a cast the patient may be allowed up within a few days, provided he is comfortable and in no pain. If gradual hyperextension is instituted or if other injuries make bed rest necessary, the cast may be omitted by placing the patient in the supine position over a Bradford frame bent at the site of fracture. Detailed studies by Baab and Howorth (34) reveal that, with average immobilization, 94 per cent of spine fractures gradually recompress to their original deformity, three to six months later. To prevent this, a special hyperextension jacket has been devised by Fisher and Maxwell (35).

Fractures of other parts of the vertebrae—such as the spinous or transverse processes,

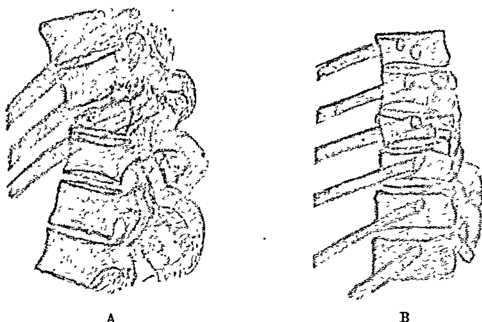


Fig. 36. Compression fracture of the body of the ninth dorsal vertebra in a 53-year-old woman who fell out of a second story window. The illustrations are drawings made from the lateral x-ray films, A, before and B, after reduction. The patient was hyperextended over a bent Bradford frame for several weeks and a plaster cast then applied. Paralysis and incontinence were complete on admission but slowly disappeared. The Queckenstedt test revealed no spinal block, although spinal fluid was bloody.

lamina, and articular facets—are more rare and some of them difficult to demonstrate even in the x-ray. The clinical manifestations consist of local pain and tenderness, rarely deformity. Prolonged immobilization is the proper form of treatment.

Traumatic spondylitis (Kümmell's disease) is a painful lesion of the spine associated with a definite kyphos (gibbus) and occasionally with manifestations of spinal cord compression. It is presumably due to a compression fracture which had been overlooked or inadequately treated. Treatment consists of prolonged immobilization in a hyperextended position.

Cervical Spine. This part of the vertebral column is more movable and hence more easily dislocated than fractured. The force producing the dislocation may be trivial, such as a sudden twist of the neck, but is usually a severe blow or fall on the head which is transmitted to the spine. The clinical diagnosis of a cervical spine injury is usually easy because of the pain produced on movement of the neck and the abnormal position in which the head is held. Fracture dislocations are common and unfortunately are more serious even than dislocations. Whiplash injuries sustained in automobile accidents are quite common and are often associated with fractures which are usually not diagnosable without x-ray aid (36).

Dislocation of the Articular Facets. The most common lesion is an *unilateral dislocation* of the articular facet, usually of the third, fourth, or fifth vertebra, which is displaced anteriorly over the one beneath (Fig. 37). This is usually evident in the lateral x-ray film because the body of the dislocated vertebra is dislodged forward (Fig. 38). The patient's head is turned away from the dislocated side, the chin elevated, and the head flexed toward the lesion, producing an attitude similar to that in torticollis. Attempts at rotation of the head toward the dislocated articular facet meet a definite block and produce severe pain. When both facets of the vertebra are dislocated, the head and chin are forward and movement to either side is limited and painful. Much more serious are injuries to the first and second cervical vertebrae (atlas and axis), particularly if the odontoid process is fractured, because of the danger of compression of the medulla which



Fig. 37. Characteristic attitude in unilateral dislocation of the articular facets (right) in the cervical spine. This patient, a 21-year-old clerk, gave a history of having his neck manipulated as a therapeutic procedure to relieve a sore throat. X-ray revealed a dislocation of the second on the third cervical vertebra; reduction was easy.

results in immediate death. The disability and pain in fracture or dislocation of the atlas and axis are similar to, but more severe than, injuries to the other cervical vertebrae. Diagnosis depends largely on adequate x-ray films; to show the atlas and axis an anteroposterior view taken through the wide open mouth is essential.

Treatment of dislocations of the lower cervical vertebrae consists of immediate reduction by traction and manipulation. Traction may be readily achieved by means of a halter around the patient's head and a muslin band around the operator's waist; by leaning back, traction is obtained and the hands left free for manipulation. Traction should be maintained for several minutes to overcome muscle resistance (37, 38). The head is slowly rotated toward the side opposite its original displacement. Sudden movements are contraindicated. General anesthesia is necessary to overcome pain and muscle spasm. The reduction is usually evident by a bone click and by the complete mobility produced; it should

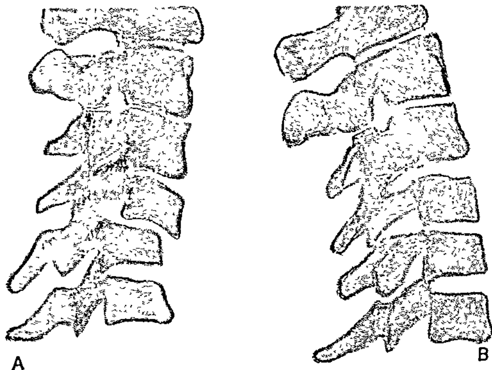


Fig. 38. Marked forward displacement of fourth on fifth cervical vertebra due to a dislocation of the left articular facet. The patient, a 40-year-old chauffeur, could not turn his head to the left and suffered pain and weakness of the left arm and shoulder which disappeared completely after reduction. A, before reduction, and three weeks after an auto collision in which the patient was thrown violently from his car; B, after reduction, while patient was in a plaster cuirass, similar to that illustrated in Figure 39.



Fig. 39. Plaster cuirass for immobilization of the cervical spine. This type of fixation is commonly used for immobilization after reduction of a dislocated cervical vertebra or for a fracture of one of the vertebrae. In six or eight weeks it may be replaced by a collar brace.

be verified by a lateral x-ray film. Immobilization is achieved by a plaster cast (Fig. 39) for a few weeks, after which period a leather or celluloid collar may be substituted. If primary reduction is unsuccessful, open reduction should be undertaken. This procedure, however, should never be attempted except by men experienced in the field. Intubation anesthesia, correct placement of the patient on the operative table, adequate exposure, and accurate hemostasis cannot be left to chance. The treatment of injury of the atlas and axis consists of immobilization in a plaster cast which protects the base of the skull and immobilizes the spine down to the pelvis. Manipulation is avoided to minimize the danger of medullary compression.

Any patient suspected of having a fracture or dislocation of the cervical spine must be transported with great care with the head firmly immobilized; danger of damage to the spinal cord is ever-present until fixation is adequately achieved.

Fracture of the Cervical Vertebrae. These injuries (Fig. 40) are very serious, often resulting in death because of spinal cord damage. Patients with such injuries, or suspected of having such injuries, must be handled with extreme care lest manipulation of the neck cause cord damage by laceration with the bone fragments. Treatment is conservative except in rare instances when there appears to be progressive hemorrhage or penetration of the cord by a fragment of a vertebra. Traction with maintenance of the usual cervical lordosis is the treatment usually utilized. A canvas sling or Crile head halter may be used, thus avoiding any cperative procedure. The latter obtains its traction without any sling around the chin, thus being slightly more comfortable than the canvas sling; its purchase is obtained by pressure of the apparatus against the forehead and occiput. If the head injury involves the chin and forehead, traction can be achieved by the Crutchfield or Barton tongs; each type can be anchored in the outer table of the skull by inserting the prongs in a small drill hole in the bone. The former is anchored in the vertex of the skull and the latter in the parietal bosses. Traction must be maintained for 8 to 12 weeks; however, when the sling or head halter method is utilized, the traction should be released carefully every few days to inspect the pressure points of the bandage for skin damage which is not uncommon with traction of this type.

Ribs. *Fractured ribs* are frequent in any crush injury and, if the patient is conscious and rational, produces characteristically sharp pain on deep respiration. The acts of sneezing and coughing are particularly painful. A history of difficulty in getting in or out of bed because of pain in the neighborhood of the fractured ribs is almost always obtainable. To protect the injured bones from movement, the patient will frequently use only abdominal respiration. Palpation of the individual ribs will nearly always indicate the site of fracture by eliciting the point or points of maximum tenderness. X-ray films may reveal the fracture but, in general, are comparatively unreliable, particularly if there is no displacement and the break is in



Fig. 40. Longitudinal fracture of the body of the fifth cervical vertebra. X-ray reveals displacement of the anterior fragment, and a loss of the normal cervical lordosis. This patient had transient neurological finding of the upper extremity. Cervical traction was used for six weeks followed by a cervical torso cast for three additional months.

the axillary line (unless a lateral or oblique view is also obtained).

Associated with fractured rib, and of much more serious significance, is injury to the underlying lung. The existence of subcutaneous emphysema (a crepitant sensation on light palpation) is suggestive of pulmonary lacerations; the presence of air and blood in the pleural space (pneumothorax and hemothorax) is more conclusive; occasionally hemoptysis occurs. Physical examination will reveal evidence of pneumothorax and hemothorax, but an adequate x-ray is most conclusive of all. The x-ray should be taken in the upright position to show a fluid level, or if that position is inadvisable, an anteroposterior view should be taken with the patient lying on his sound side. The presence of collapsed lung, shifting of the trachea and heart, as well as the demonstration of a fluid level, are of special significance. Clinical manifestations of lung damage may be absent, but such evidence of respiratory difficulty as a rapid rate and cyanosis indicates serious impairment of gaseous interchange and makes treatment more urgent.

In simple fracture of the ribs, *treatment* is directed toward immobilization of the thorax, largely to relieve pain. This is best achieved by a firm circular bandage applied at the time of deep expiration when the chest is collapsed. A chest binder may also be used. Elastic adhesive (elastoplast) applied completely about the chest in expiration is effective and comfortable. Adhesive strips which embrace half the thorax are ineffective. However, adhesive strips placed all the way around, except for about two inches on the side opposite the fracture, will be fairly effective in supplying immobilization and relieving symptoms. Relief of pain and easier respirations should follow the application of an adequate support. Codeine sulphate (0.25 grain or 0.5 grain) should be given every

four to six hours during the painful stage. This treatment is performed even in the face of internal injuries which are insufficient to demand more than rest and conservative care. The operative and other treatment of the injuries to the lung associated with fractured ribs are described in Chapter 36.

Sternum. Fractures of the sternum may be produced by direct blows or crush injuries, but are comparatively rare. Manifestations consist of tenderness over the line of fracture and pain in this area upon deep breathing, coughing, and so forth. The patient prefers to allow the head and shoulders to droop forward, since this position relieves the pain. Since the fracture line can rarely be palpated, any patient complaining of significant pain and tenderness in the region of the sternum should have an x-ray. Usually only the lateral view is of any value. Displacement of fragments should be corrected if possible, but healing with fragments in poor position is rarely accompanied by any permanent difficulty. If pain is considerable, strapping with adhesive may be inadequate and immobilization in bed may be necessary. Contusion of the heart may complicate injuries of the sternum (Beck).

THE SKULL

Although the serious aspects of head injuries are frequently thought of as being produced by fracture of the skull, in reality they are secondary to intracranial injury and increased intracranial pressure. Naturally, fracture of the skull may be accompanied by tenderness along the fracture line, but even this manifestation, which is so consistently present in other fractures, may be absent. Therefore, it may not be possible to make an accurate diagnosis without an x-ray, except through manifestations produced by the intracranial injury. Obviously, bone fragments may actually be visible in compound fractures, and deformity demonstrated in depressed fractures. However, since most of the manifestations and serious effects encountered in fractures of the skull are secondary to intracranial injury we have included the entire subject in the chapter dealing with the nervous system.

THE FACIAL BONES

PAUL W. GREELEY

Principles in the Diagnosis of Fractures. Clinical diagnosis of fractures of the facial bones can be made with a high degree of accuracy (39). An ecchymotic orbit is suggestive of a malar bone fracture. Palpation for irregularities of the orbital floor, flattening and depression of the malar eminence, and subjective complaints of diplopia and numbness along the distribution of the infraorbital nerve make the probability of malar fracture quite certain. A concave depression over the zygomatic arch suggests a depressed fracture in this area. Depression of the bony fragments may press against the underlying coronoid process and make opening of the mouth difficult or impossible. Tenderness along the mandible in one or more areas, together with irregularity of the lower teeth, suggests mandibular fracture. The maxilla may be movable and even found dropping downward into the mouth. Nasal fractures are usually depressed or lateral, depending upon whether the force of injury has been applied from in front or from a blow on one side. Inspection of the nostrils may reveal dislocation of the lower end of the septal cartilage into either nasal airway. The above findings naturally must be confirmed by x-ray studies for obvious reasons.

In the treatment of extensive facial injuries, whether they involve soft tissues or fractures, or both, the establishment and maintenance of an airway is imperative. As stated previously, this may necessitate an emergency tracheostomy as the initial part of the treatment.

Except for certain nasal fractures, endotracheal general anesthesia should be given priority.

Nasal Bones. Nasal fractures can ordinarily be manipulated with the aid of an intranasal elevator or Walsham forceps, using the thumb and index finger of the opposite hand to palpate the external alignment of the nasal arch bones. If the septal cartilage has been dislocated out of its bony groove, it must be manipulated back into position with an Asch forceps. Once reduction has been secured, a piece of vaseline gauze is packed loosely into each nasal airway to maintain

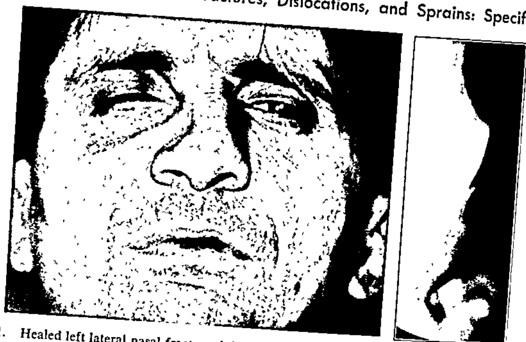


Fig 41. Healed left lateral nasal fracture deformity. Note deflection of nose and adjacent x-ray which reveals a typical fracture.

Fig. 42. Schematic anatomic drawing to show method of insertion of elevator into antrum to elevate depressed malar bone fracture.

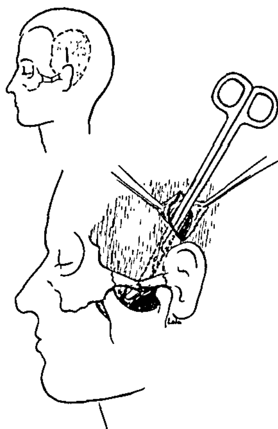


Fig. 43. Gillies' method of elevating depressed fractures of the zygomatic arch. An incision through a shaved area in the temporal region is made through the skin and temporal fascia. An elevator is then passed between the temporal fascia and temporal muscle until it comes to lie beneath the zygomatic arch fracture. The depressed fragment can then be manipulated upward into normal position.

position of the fragments in normal alignment. External fixation is rarely indicated. The vaseline packs are removed in two to four days.

If early reduction of the bony and septal segments is not carried out, they will heal in malposition (Fig. 41). This will necessitate a more complicated procedure of open reduction and sometimes submucous resection at a later date.

It is easy to overlook a nasal fracture in a small child. A minor displacement at this age frequently damages the epiphysis. This in turn will cause the nose to become distorted as growth and development follow.

The Zygoma (Malar Bone). Simple or comminuted depressed fractures of the malar bone can be elevated through the transantral approach. A small incision is made in the upper buccal sulcus. An elevator is then slipped into the antrum, beneath the malar bone (Fig. 42). The fragments are then lifted or molded upward into normal anatomic position. An iodoform gauze pack is then left in the antrum beneath the malar to hold it in position until early union occurs. The pack may be removed in seven to ten days.

Fractures of the zygomatic arch are reduced by the method originally described by Gillies (40) (Fig. 43). Once reduced, the fragments will stay in position without other fixation because of the arched shape of the bone.

The Maxilla (Upper Jaw). Complicated fractures of the maxilla and mandible present more difficult methods of therapy. We are very much opposed to the use of any type of traction apparatus applied from a plaster of paris head cap. We feel that this gear is uncomfortable to the patient; it may produce pressure necrosis of the scalp and forehead skin; and, in many instances, it fails to reduce the fracture. Traction-suspension apparatus with the patient in bed for several weeks has no practical place in present-day management of maxilla fractures. Likewise, the use of external pin fixation in the treatment of mandibular fractures must be considered archaic. Pin sequestra, infection, and severe postoperative pinhole scars are inevitable.

As an alternative, we prefer to treat complicated facial bone fractures as one would do with a complicated fracture of the tibia or femur, i.e., by open reduction. Properly executed, the reduction and fixation can be made accurate, and complicating infection is negligible. Furthermore, it is a very comfortable method for the patient and ordinarily involves but a few days' hospitalization (Figs. 44, 45).

Fractures Through the Central Third of the Face. These fractures are usually accompanied by a downward displacement or "floating" of the maxilla (Fig. 44). The maxilla should be lifted into normal position and held there by an assistant. A Kirschner wire is then driven through a fixed point of the malar-zygomatic compound on one side and a similar one from the opposite side (Fig. 45). The Kirschner wires are clipped off just

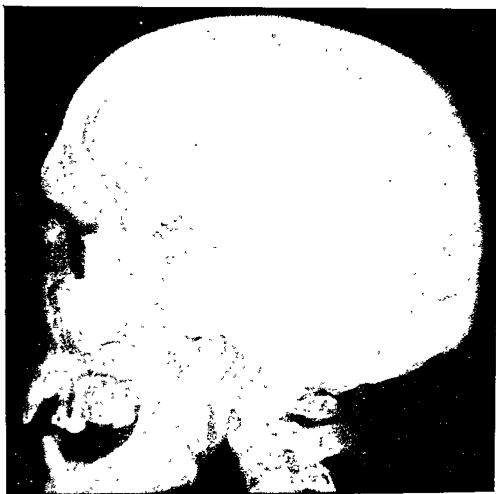


Fig. 44. Fracture of the facial bones. The nasal bony arch and maxilla have been displaced forward and downward. There is also a fracture of the mandible which does not show on this view.

beneath the skin. This fixation holds the maxilla in excellent position in a comfortable manner for the patient. The wires are removed in approximately eight weeks.

The Mandible. The management of uncomplicated fractures of the mandible can ordinarily be handled by simple interdental wiring, with or without elastic traction, as indicated. Fractures of the alveolar ridge can usually be maintained in good position with an arch bar secured to the teeth. Fractures of the condylar head or condylar process do not ordinarily need any special attention unless they are displaced in such a manner that normal temporomandibular joint function is impaired. Open reduction in these instances is not ordinarily as successful as complete removal of the displaced fragment. Temporary interdental wiring for two to three weeks may add to the patient's comfort.

Sometimes one is confronted with a tooth in the line of a mandibular fracture. If left in position, the tooth is apt to provide a direct communication from the oral cavity into the fracture site. This may lead to infection; hence such a tooth is frequently removed.

Complicated and multiple mandibular fractures and those in edentulous patients are exposed through small external incisions. The bone ends are secured by direct wiring with stainless steel through small drill holes placed near the fracture site (Fig. 45). If fractures of the mandible are neglected, nonunion and osteomyelitis are apt to result (Fig. 46).

Dislocation of the Jaw. Dislocation of the jaw is a relatively uncommon injury; the condyles are usually displaced forward, i.e., anteriorly. The mouth is held open. Pain is moderate and talking or chewing difficult, if

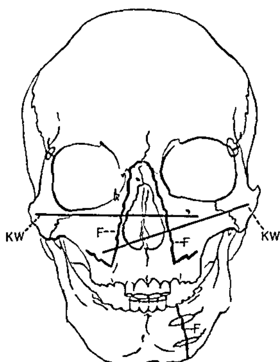


Fig. 45. Fracture after reduction and fixation. Same patient as in Figure 44. The central third bony structures (superior maxilla and nasal bony arch) have been reduced to normal position and secured by two Kirschner wires. Mandible fragments held by two stainless steel wire loops placed through drill holes. F indicates fractures, and KW indicates Kirschner wires.

not impossible. Reduction is effected by placing the thumbs in the mouth on the lower molars and depressing the mandible downward while it is at the same time being pushed posteriorly. (The operator should always protect his thumbs by wrapping a towel around them. Failure to do this may cause a crushing injury to the thumbs when the mandible snaps back into normal position). Reduction may be attempted without anesthesia; but anesthesia of some type, preferably ether or pentothal, is usually necessary. The patient should be instructed not to open the mouth very widely for two or three weeks after reduction, since dislocation might easily recur by such a simple mechanism as yawning.

Repeated mild dislocation of the temporomandibular joint is a frequent cause of chronic pain for which many patients seek relief. Often they complain also of an annoying click whenever the jaw is used. Relief may often be obtained by using only the molar teeth for chewing and avoiding the use of the incisors for biting. Although operative therapy has been used for the severe cases, Schultz has described a simple method by which a fibrosis and shortening of the joint capsule is achieved by the intraarticular injection of a solution of sodium psylliate.

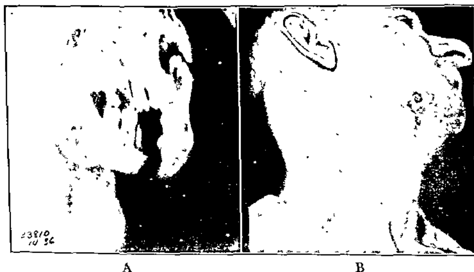


Fig. 46 Untreated fracture of mandible. A, x-ray at time of admission, five weeks after injury; note separation of fragments. B, patient developed an abscess which ruptured spontaneously with the formation of a sinus as noted in the photograph. An osteomyelitis is now present.

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24

THE ORGANS OF MOVEMENT

PHILIP D. WILSON

The organs of movement include bones, joints, bursas, tendons, and muscles, and diseases affecting them are commonly the cause of serious disability. This is true not only because they are subject to frequent injury and infection and are involved in systemic disease, but also because of their dense rigid structure and relatively poor blood supply, particularly bones and joints; this last factor probably accounts for their slow and often imperfect power to overcome the effects of disease. Of special importance, too, is the tendency for bone, joint, and muscle to suffer from serious disability through rest or disuse. Since immobilization is an important aid in treatment, particularly of injuries and infections, it is obvious that such deletorious changes are to be prevented if possible. The term *atrophy of disuse* is used to describe the changes which follow prolonged immobilization (Fig. 1). These changes include atrophy of muscles, decalcification of bone, and stiffness and even fibrous ankylosis of joints. They begin very soon, but are apparent only after a few weeks, and become pronounced after months. Care should be taken in each case to utilize only a sufficient period of rest to allow healing without inducing atrophy of tissues. This is often a difficult problem because the healing of bone and joint injuries, and especially infection, frequently requires many weeks and months and sometimes years. Though the organs of movement, per se, are not vital structures and are not often the seat of diseases which endanger life, they play an important part in our socio-economic structure. Diseases of these organs are frequent causes of loss of time in industry and constitute the main basis for workmen's compensation laws. They, therefore, have a great medicolegal importance.

Many of the diseases discussed in this chapter "belong" to the field of orthopedic surgery and are therefore considered only in basic and general terms. Detailed descriptions may be found in textbooks on orthopedic surgery, particularly those of Howarth (1), Luck (2), Ferguson (3), Ropes (4), Campbell (5), and Mercer (6). Of the various lesions which affect the organs of movement, fractures are described in separate chapters. The others are classified in terms of the specific tissue involved.

BONE

Bone is subject to trauma, neoplasm, and infection and is the site of constitutional diseases and congenital deformities. Only the last two groups are described herein; the first and second have been discussed in preceding chapters.

Pyogenic Osteomyelitis. Modern chemotherapy, as discussed in a separate chapter, has revolutionized the clinical diagnosis and course of acute osteomyelitis, as described especially in Chap. 5 (Figs. 2, 3). To a considerable extent, therefore, the following details (except for the early clinical picture) are largely of historical interest. However, it is likely that more of the original later manifestations of these infections may be seen in the future as more of the organisms, espe-

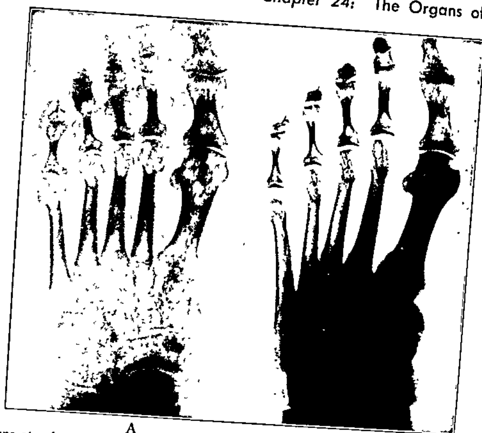


Fig. 1. Bone atrophy. A, bone atrophy revealing extreme decalcification in the foot of a 48-year-old man after prolonged immobilization because of an infected compound fracture of the leg; B, a normal foot of a man of the same age for comparison.



Fig. 2. Acute osteomyelitis of the tibia. Lateral and anteroposterior radiologic views show early, barely detectable changes. The changes in density are slight but can be seen just above the epiphyseal line. The disease started apparently five days previously. It is unusual for roentgenologic changes to occur this early. Operation was performed a few hours after admission. A huge subperiosteal abscess was encountered; a large amount of pus was also present in the medullary cavity. Adequate drainage was instituted and a plaster cast was applied. Extensive destruction of bone had already taken place at the time of operation; this is apparent from the bone involvement which ultimately showed up in the x-ray (see Fig. 6). Staphylococcus was the causative organism. Chemotherapy even if started at the time of admission would have prevented the subsequent course (See Chap. 5).



Fig. 3. Acute osteomyelitis of the tibia. Roentgenograms shown above were obtained from a six-year-old girl, who entered St. Louis Children's Hospital six days after the onset of pain in the left leg followed by fever and rapidly increasing prostration. On admission she was almost moribund, with signs of overwhelming infection, temperature 41° C. (106° F.), uncountable pulse and rapid respirations; the lips and finger tips were cyanotic. The entire left leg was tremendously swollen and red. Supportive therapy and penicillin injections were carried out. The general condition improved. In a week simple incisions of the skin of the leg yielded a large amount of pus from the subcutaneous tissues, from which a pure culture of *Staphylococcus aureus* was grown, the same organism as was obtained from the blood. X-ray at this time (a) was negative. Improvement was slow but continuous. Two weeks later or four weeks after onset the x-ray (b) showed changes for the first time, which involved the entire shaft. Improvement continued and the patient went home in a cast over the draining wounds. Four months after onset, x-ray (c) revealed a spontaneous fracture. Dead bone could be seen in the wound and a simple sequestrectomy was therefore carried out. The wound discharged small bits of bone spontaneously thereafter, but eventually healed. The x-ray (d) was obtained seven months after onset and shows satisfactory progress. The x-ray (e), 18 months after onset, shows *complete solidification. The patient attends school and has little if any deformity* or disability aside from the scars on her leg and has had no recurrence. *Note* that several weeks passed before roentgenologic changes were visible in the bone. Note also the extensive changes in the upper part of the tibia shown in (b) which gradually disappeared without operative interference. Without penicillin this patient would probably have succumbed to the systemic effects of the severe infection, or, if she had recovered, complete sequestrectomy of the entire shaft would have been eventually necessary. Had penicillin been started earlier the extent of bone involvement would have been greatly reduced or even entirely eliminated.

cially the staphylococcus, are becoming insensitive to penicillin and other antibiotics. Moreover, neglected disease, even in spite of progress in chemotherapy, is still being seen, especially in certain parts of the world not blessed with all the good things of life, including antibiotics. Pyogenic osteomyelitis may be considered in three groups: 1. acute primary, 2. secondary, and 3. chronic osteomyelitis.

1. *Acute Primary Osteomyelitis.* As a primary infection, acute osteomyelitis is not un-



Fig. 4. Neglected acute osteomyelitis. The patient, a 12-year-old girl, was treated as a case of "rheumatism" for four weeks before admission. X-ray showed involvement of the entire shaft of the tibia. As can be seen from the photograph, the leg was literally a "bag of pus"; this was confirmed at operation when a large quantity of staphylococcus pus was evacuated.

common in childhood but is rare in adult life. It is a hematogenous infection of bone due to the staphylococcus (Fig. 4), occasionally the streptococcus which is considered separately. Not infrequently the infection seems to arise from some obvious pre-existing lesion—such as a furuncle, septicemia, otitis media—but more commonly through some occult or unknown portal of entry. Accordingly there is always a bacteremia, and often a septicemia, present before the osteomyelitis develops. There is frequently a history of injury at the site of the infection, but its etiological importance is unestablished. The organisms lodge in the marrow cavity of the metaphysis, presumably because the terminal capillary loops at the epiphyseal line empty into large venous sinuses where the blood current is slowed sufficiently to allow the bacteria to gain a foothold and multiply. The resulting acute inflammatory reaction being in the closed bony structure develops extreme pressure and causes intense pain and disability. The infection spreads by direct extension. It rarely if ever breaks through the epiphyseal line into the epiphysis, but it penetrates the cortex through the Haversian canals, a process which usually takes a number of days. In any case, pus finds itself under the periosteum which it strips away from the bone, thus forming a subperio-teal abscess which sooner or later ruptures into the overlying soft tissue and ultimately forms a subcutaneous abscess. Of greatest significance in this process is the actual amount of bone infected and killed by the disease. This is not apparent until later, but it determines the further course of events. In the severe cases the entire shaft may become necrotic. On the other hand, the infection may break through the cortex so soon (or with the aid of the surgeon's drill) that very little bone is killed (Fig. 5). Although the infection rarely penetrates the epiphyseal line, pyogenic arthritis may occur after pus has appeared under the periosteum and extended from this point into the joint.

Reparative processes begin first by the separation and partial phagocytosis of necrotic bone which becomes demarcated from the viable cortex and is called a *sequestrum*. Secondly, nature begins to build new bone to take the place of that destroyed by the infection. Osteogenesis occurs from the lifted up periosteum and probably begins early, although it cannot be seen roentgenologically for two or three weeks. The new bone is called *involucrum;* it eventually becomes dense, hard, and rich in calcium, and replaces the necrotic bone. It develops in the presence of the sequestrum and even while the tissue is bathed in pus, regardless of whether treatment has been instituted or not. On rare occasions the infection does not extend or penetrate, but forms a localized lesion in bone, called *Brodie's abscess,* which ordinarily develops insidiously and is really a manifestation of chronic osteomyelitis. From the primary bone lesion, metastatic foci may develop. It is not uncommon for several bones to become infected one after the other. In a few unfortunate children this succession would continue for years so that eventually most of the long bones became the site of osteomyelitis. The bones commonly in-

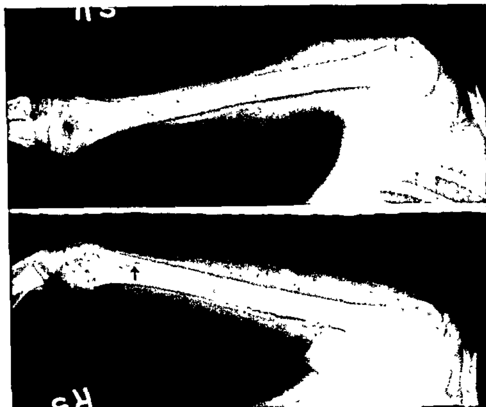


Fig. 5. Acute osteomyelitis of the humerus in a girl ten years of age; the anteroposterior and lateral roentgenograms were taken three weeks after onset. The arrow points to some of the decalcified areas of the osteomyelitis. Involucrum has already developed and may be seen on each side of the shaft. (Courtesy, Dr. Robert Ray.)

volved, in order of their frequency, were tibia, femur, humerus, radius, ulna, fibula, and the metatarsal bones. Abnormal lengthening of the affected bone occurred in many children after many months, apparently due to the increased blood supply, the hyperemia at the epiphyseal line augmenting local bone growth (Trueta). When the epiphyseal plate was destroyed, shortening of the limb resulted.

Clinical manifestations are systemic and local. The former are those of general septicemia and include fever, chill, leukocytosis, rapid pulse, and prostration. The severity of the systemic manifestations vary with the virulence of the organism. In adults, the general reaction is apt to be less severe; subacute and chronic forms are more frequently encountered in which the infection develops slowly. The local signs and symptoms in the typical acute case are those of a deep-seated infection. The pain is severe and located over the end of the bone close to the joint. While muscle spasm is present to a slight extent, the joint can be moved somewhat without increasing the pain. Acute tenderness over the involved bone on deep palpation is one of the earliest signs. In eliciting this tenderness the bone is carefully palpated, starting at some distance from the lesion which is approached gently and gradually in a manner similar to that used in the detection of point tenderness over a fracture. The overlying tissues may be swollen and edematous, but the skin itself is not red or tender during the early stage of the disease. If the infection has been present for several days there may be evidence of a local abscess, i.e., swelling, redness, local heat, and fluctuation.

Streptococcal osteomyelitis differs considerably from osteomyelitis produced by the staphylococcus. The former much more commonly occurs as a metastatic invasion of the bone from a primary source—such as otitis media and mastoiditis. The manifestations of the streptococcal osteomyelitis are apt to develop more insidiously than the staphylococcal infection. The pain is not so severe;

swelling and subcutaneous suppuration develop more slowly and less commonly. There is less destruction of bone; sequestration is therefore less marked. Many such lesions will subside without gross suppuration when properly treated with antibiotics. They are particularly prone to occur in infants under two years of age.

Diagnosis, though more difficult when the patient is seen early, should be made as soon as possible, because of the need for prompt treatment. The diseases which may be confusing are acute rheumatic fever, acute pyogenic arthritis, and acute cellulitis; the differential diagnosis is discussed on page 544. X-ray is disappointing because the earliest roentgenologic evidence of acute osetomyelitis is absorption of bone which ordinarily is not demonstrable for a week or more following the onset. Involucrum formation is seen when new bone becomes deposited under the elevated periosteum and requires at least two weeks. Sequestration may not be demonstrable for an even longer period. The local signs and symptoms are, therefore, of greatest importance and should be carefully noted; and examination should be repeated at short intervals if necessary.

The *treatment* of staphylococcal osteomyelitis was revolutionized by the introduction of penicillin therapy. If the patient is seen within a day or two of the onset of the infection, i.e., before necrosis of bone has occurred, chemotherapy will permit healing without operation. Even if there is evidence of suppuration, operation may often be avoided even if it is against the principle that the presence of pus requires incision and drainage, regardless of the influence of chemotherapy. For example, Altemeier and Helmsworth (7) presented evidence of excellent results following penicillin therapy in which operation was postponed indefinitely and used later only when spontaneous drainage appeared inevitable or a well-developed sequestrum was demonstrable. Even in the days before chemotherapy, operation in acute osteomyelitis was not an extensive procedure and consisted merely of drainage of pus by incising the periosteum and, in many instances, placing a simple drill hole into the metaphysis close to the epiphyseal line, which, however, could not be injured because of the danger of growth disturbance. On the other hand, if the hole were drilled too far from the epiphyseal line the metaphysis would be missed, or still worse the open medullary cavity of the diaphysis would be entered with danger of spreading of the infection to the entire shaft. At most, the bone between such openings was removed to permit more ready drainage, but extensive resection of the cortex was unnecessary and deleterious. The wound was left open. Later petrolatum packs containing tubes were inserted for the local instillation of penicillin solution. Frequent dressing was condemned because it was painful and deleterious. Orr (1927) popularized the idea of immobilization of the extremity in a plaster cast. The effectiveness of this method was established by much clinical experience. Such a cast, left in place for three or four weeks, obviated the need for dressings and produced complete rest and alleviation of the local pain. An excellent study of acute osteomyelitis before the days of chemotherapy is that of Miller (8).

As already suggested, the treatment of streptococcal osteomyelitis even before chemotherapy was often nonoperative. Surgical procedures were delayed even when a localized destruction of bone was observed in the x-ray. Incision of superficial abscesses as they developed was obviously indicated. The introduction of chemotherapy has added further justification for this attitude.

2. *Secondary Osteomyelitis.* This term is used to describe a variety of bone infections in which the infection arises, not in the bone itself but elsewhere, and involves the bone secondarily, usually by direct extension. A common type is that which may follow compound, or open, fractures. Secondary osteomyelitis of the jaw often develops by extension from a cellulitis about a tooth. If the tooth is pulled at the improper time, osteomyelitis is particularly prone to develop and may lead to severe systemic manifestations. The terminal phalanx becomes the site of osteomyelitis following a neglected felon. The other phalanges are frequently infected secondarily from acute suppurative tenosynovitis. Osteomyelitis of the tarsus is sometimes secondary to penetrating infections and may eventually involve the entire foot. Am-

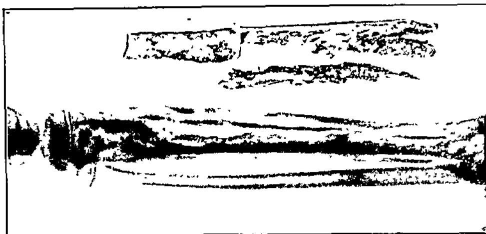


Fig. 6. Chronic osteomyelitis. The patient was a six-year-old boy. The early stage in this patient is presented in Chapter 24, Figure 2. The x-ray film illustrated was taken three months after the first operation and just before sequestrectomy. A photograph of a portion of the sequestra which were removed is also shown. A cast was reapplied; two months later the wound was almost completely healed by granulation.

putation is often necessary as a last resort. The patella and olecranon are sometimes involved by direct extension from an overlying lesion. Osteomyelitis of the skull is secondary to compound fracture, neglected sinusitis or avulsion of the scalp. Osteomyelitis is always suspected when an abscess or infected wound located near bone fails to heal and forms a chronic draining sinus. X-ray may enable one to make a definite diagnosis. During the acute stage, treatment is that of the primary lesion.

Treatment of secondary osteomyelitis depends on the nature of the primary lesion and the bone affected. Although most types heal readily, the osteomyelitis following compound fractures has always presented a choice of nonoperative versus operative therapy. The problem is somewhat similar to that in chronic osteomyelitis which follows a primary infection of bone and is discussed in more detail under the next heading.

3. *Chronic Osteomyelitis.* This lesion is the outcome of acute or secondary osteomyelitis which has resulted in necrosis of bone (Fig. 6). Its severity depends on the extent of bone killed by the infection which, as already stated, is influenced to a large extent by the promptness of chemotherapy and/or operation in the acute stage of the primary disease. An extremity which is the site of chronic osteomyelitis shows considerable muscular and bone atrophy and exhibits one or more draining sinuses leading to diseased bone (Fig. 7). X-ray will reveal the extent of the lesion and often will clearly demonstrate the site and size of sequestra.

Treatment of chronic osteomyelitis following an acute primary osteomyelitis in its early stages is, to a large extent, nonoperative. When the infection involves a long bone of an extremity, protection of the limb is important to avoid the danger of fracture before a strong involucrum forms. This, indeed, is all that need be done in most patients. Small sequestra are often discharged from time to time or are absorbed. However, as long as dead bone remains, it acts as a foreign body and permanent closure of the sinus will not occur. With adequate chemotherapy the sequestrum may become revascularized, act as a bone graft, and become incorporated into the living bone, particularly if the pus surrounding it is absorbed or evacuated aseptically and without producing secondary infection. Operation for removal of sequestra may be carried out as soon as there is roentgenologic evidence that separation between the dead and living bone is well under way and that there is a well-developed involucrum. Operation may also be necessary to drain abscesses or cavities which have formed since the initial osteotomy, or as a primary manifestation (Brodie's abscess). Such operations, however, should rarely be extensive

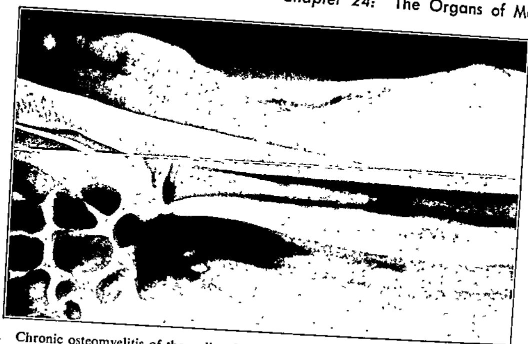


Fig. 7. Chronic osteomyelitis of the radius. The patient was an eight-year-old boy. An operation for the acute infection was performed 10 days after onset; x-ray was entirely negative at this time. The wound discharged small sequestra from time to time, and one large one was removed operatively, represented by the bone defect in the x-ray. The photo represents the almost healed incision, the radiograph, the end result of bone repair; both were taken nine months after onset. The patient has full use of the arm and atrophy has completely disappeared.

except when the dead bone to be removed involves nearly all of the diaphysis. Healthy bone is resected only to remove loose sequestra or to open and drain residual abscesses; saucerization to eliminate dead spaces is, however, justified. Wounds are left wide open, packed with petrolatum gauze, and a plaster cast applied.

The great difficulty with the conservative treatment of chronic osteomyelitis as just presented was the long period of disability it produced, due to the fact that chronic sinuses failed to heal. Radical operation for the removal of dead tissue and elimination of dead space has been greatly stimulated by the introduction of chemotherapy. At first it was thought that penicillin or other antibiotics alone would permit these wounds to heal. This hope was not fulfilled due undoubtedly to two factors; first, the presence of mixed infection, and second, the existence of necrotic tissue in the wound, into which penicillin could not penetrate. However, with chemotherapy, earlier operations are now safe and effective, even permitting primary enclosure with a high incidence of primary healing. In this way, months have been saved in the treatment. With the aid of chemotherapy, the fear of spread of infection, which occasionally followed any attempt at surgical closure, has been greatly reduced.

The experience in World War II with chronically infected compound fractures has also shown the great value of chemotherapy in association with properly timed and adequate operation. This included the use of skin grafts over large granulating areas as well as extensive excision of nonviable or chronically infected tissue and obliteration of cavities. In many cases, chronic osteomyelitis following fracture has even been prevented by closing contaminated wounds relatively soon after injury (delayed closure). The primary healing thus achieved saves countless months of disability.

Tuberculosis of Bone. The distinction between tuberculosis of the bone and of the joint is not always clear since the tubercle bacillus often seems to attack both structures together (see p. 546). In the *spine* (Pott's disease) (Fig. 8), it starts in the vertebral body, destroying it and the associated intervertebral disc, producing a deformity (gibbus, kyphosis). Usually a cold abscess is formed which, in tuberculosis of the lumbar spine, may burrow along the psoas muscle

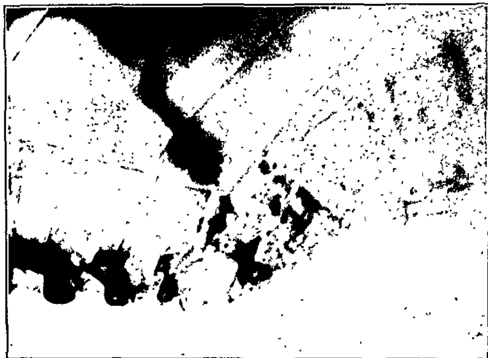


Fig. 8. Tuberculosis of the spine (Pott's disease). The patient was a 13-year-old girl. The roentgenogram reproduced above is a lateral view and shows the destruction of the bodies of the eleventh and twelfth vertebrae, and the marked angulation. However, no signs of spinal cord pressure were present. The disease started six years previously with a reputed injury followed by persistent pain in the back. The child's complaints were minimized until an x-ray revealed the true diagnosis six months later. Following the unsuccessful use of more conservative measures spine fusion was performed. This operation is an ankylosing procedure which immobilizes the spine by creating a bony arthrodesis between the lamina, the articular facets, and also between the dorsal spines. (Courtesy, Dr. F. A. Jostes.)

and present in the groin as a psoas abscess. It does this so silently that the fluctuant inguinal mass may be mistaken for a hernia. The cervical spine is also involved and may be associated with a cold abscess of the neck. Occasionally abscess or tuberculous granulation tissue invades the spinal canal and, in association with the kyphosis, produces pressure on the cord, and a spastic paralysis ensues. The head of the *femur* is also frequently involved, especially in children, but the clinical manifestations are so distinctly referable to the joint that it will be included under joint disease. Another favorite site of bone tuberculosis, in Negroes at least, is the sternal end of the *clavicle*.

Tuberculosis of bone heals by fibrous replacement or by ankylosis when joints are involved. The disease responds slowly to treatment, which is largely an orthopedic problem and consists of *immobilization, nutritional care*, and chemotherapy It should be emphasized that, as a rule, healing is best achieved by ankylosis of the adjacent joint surfaces involved. (See also under Tuberculosis of the Joints.)

Syphilis of Bone. Three types of disease are recognized, although now increasingly rare due to the wide use of chemotherapy: 1. Syphilitic periostitis (Fig. 9) consists merely of a thickening of the periosteum with a roughening of the bone and is commonly seen in the tibia. Local pain and tenderness, especially at night, are complained of in syphilitic periostitis and the x-ray may show characteristic changes. 2. A hyperplastic form occurs commonly in the sternum and the sternal end of the clavicle or the clavicle itself, simulating tuberculosis, particularly in Negroes in whom the two diseases are common. It also occurs in the shafts of long bones as a hypertrophy of the cortex and may simulate *Paget's disease*. 3. A destructive form (gumma of bone) is seen in the shaft of long bones

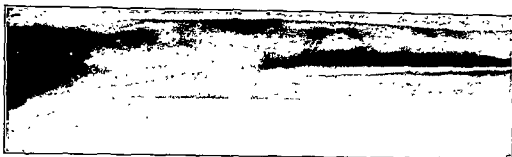


Fig. 9. Syphilitic periostitis in the tibia. Note the surface irregularity, particularly in the proximal portion of the bone. The patient, a 43-year-old woman, had pains in the legs and also had luetic ulcers.

and in the skull. In the x-ray it may simulate primary bone tumor, metastatic carcinoma, or pyogenic osteomyelitis. Diagnosis of bone syphilis is aided by the x-ray and particularly by the finding of a positive Wassermann. Treatment is medical.

Miscellaneous Diseases. These comprise the following:

1. *Rickets* (Fig. 10) is less common than formerly and has a surgical interest only in that it causes deformities in the long bones, especially "bowlegs" and "knock-knees." If the deformities persist in spite of medical treatment, osteotomies may have to be done to correct them.

2. *Osteochondritis deformans juvenilis* (Legg-Calvé-Perthes disease, coxa plana) is a disease of the capital femoral epiphysis affecting children between five and ten years of age and in the past was often confused with tuberculosis. Pain is slight, a limp is followed by atrophy and x-ray shows a progressive flattening and fragmentation of the head of the femur, which is characteristic of the disease. Treatment consists of avoidance of weight-bearing with crutches and an elevated shoe on the unaffected side. A similar lesion has been described in the tibial tubercle (Osgood-Schlatter disease) and in the tarsal scaphoid (Köhler's disease). Diagnosis is made by x-ray. Treatment consists of immobilization when pain is present.



Fig. 10. Bow legs due to rickets. Prevention of this as well as other bony deformities due to rickets is largely a pediatric and orthopedic problem. Osteotomy for correction of deformity as depicted above is carried out only after healing of the active disease has been achieved.

3. *Scurvy,* now a rare disease, is due to vitamin C deficiency and is manifested by bleeding from the gums, tenderness, and swelling of the bones about the joints. Subperiosteal hemorrhage is common and in many instances is a source of the pain. The roentgenogram is characteristic. Treatment is dietetic.

4. *Osteomalacia* is probably also due to dietary deficiencies. It is observed mostly in women. The bones become soft, lose much of their content of calcium, and are subject to fracture and deformities. Pain and stiffness are noted. Treatment is symptomatic and dietetic (vitamin D).

5. *Paget's disease* (osteitis deformans) is characterized by enlargement and distortion of bones, by pain in the limbs, by a decrease in the height, and by an increase in the size of the head (Fig. 11). The condition is uncommon. It has a long course and begins insidiously during middle life; the changes in the skeleton are usually general but are occasionally confined to a few bones, notably the skull and legs. Roentgenograms are characteristic in the osteoblastic phase and show coarse trabeculations, thickening of the cor-



Fig. 11. Paget's disease of the bone. The disease was of slow, almost imperceptible development. The photographs show a well-advanced disease in a 70-year-old male. Note how relatively long the arms are; this is due to an actual shortening of the skeleton produced by a collapse of a vertebra and a bowing of the long bones of the lower extremities. The characteristic x-ray appearance of the disease may be observed in the roentgenograms of the lower leg; note the bowing and overgrowth of the cortex, which, however, is composed of soft osteoid tissue and not true bone. (Courtesy, Dr. W. B. Gnagi, Jr.)

tex, and a loss of the clear delineation between the cortex and medullary canal. In the *osteoblastic* phase, the alkaline phosphatase is markedly elevated. In the osteolytic phase, the x-rays show destruction of bone and the alkaline phosphatase is normal. The tibias are much thicker than normal and bowed anteriorly. The vertebrae are also compressed, apparently from the weight of the body. Spontaneous fractures sometimes occur at the junction of normal and abnormal bone. *Malignant* changes do occur in the form of osteogenic sarcoma. The etiology is unknown and the treatment is merely palliative.

6. *Fragilitas ossium* (brittle bones, osteopsathyrosis, osteogenesis imperfecta) is a rare disease of bones manifested by the presence of multiple fractures after slight trauma. It may be present soon after birth and persist into, or be noted first, in childhood. Many cases are associated with blue scleras. The etiology is obscure. There is no treatment except protection of the extremities to avoid trauma. Spontaneous cure often occurs with the advent of adolescence.

7. *Achondroplasia* (dyschondroplasia) is a rare, deforming disease of the shafts of bone which softens and shortens them due to the formation of osteoid tissue which has little calcium and contains cartilage.

8. *Chondroplasia foetalis* is apparent at birth and is a complex disturbance of bone formation which causes dwarfism, deformities, and a square, large head.

9. Although the muscle paralysis resulting from *poliomyelitis* constitutes perhaps the most serious complication of the disease (except mortality) *bone shortening* takes place and may be sufficient to prevent restoration of proper function even though muscular deficiencies have been corrected. To combat *the disability incident* to the shortening, Abbott (9) has devised a very ingenious method

of lengthening the bones of the leg by operative means. This method is used only in selected cases for it has inherent many complications. *In the great majority of lower extremity length discrepancies, the normal side is shortened.* Before growth is complete, epiphysiodesis or stapling of the normal epiphysis may be done to secure equal leg lengths by the end of the growth period. Obviously this method could be utilized for bone shortening resulting from various causes (see also Wilson and Thompson, Ann. Surg., 110: 992, 1939). Bone shortening is also used to permit nerve suture in the presence of a marked defect in nerve length.

JOINTS

The anatomical structures involved in joint disease consist of the articular (cartilaginous) joint surfaces and the synovial membrane which is a continuation of the cartilaginous layer forming a closed (joint) *cavity. The synovial membrane is composed* of modified fibrous tissue cells or mesothelium which secretes mucilaginous fluid, thereby lubricating the joint surface. It is reinforced on the outside by a supporting layer of dense fibrous tissue called the *joint capsule*. Outside the joint are the ligaments, tendons, and muscles which are attached to the bone on either side and which are more important than the capsule in lending stability to the joint. In some joints there are additional structures—such as the semilunar cartilages and cruciate ligaments of the knee and the round ligament of the hip—which also help in the proper function of the joint.

Traumatic Joint Disease. The synovial fluid has recently been studied extensively by Ropes and Bauer (4). The changes in cell count, viscosity, protein (albumin and globulin), and glucose have been correlated with various pathological conditions in the joint. The reader is referred to this excellent monograph. Injury to joints alone, aside from dislocation, is probably rare because the associated structures—such as tendons, ligaments, muscles, and bone—are nearly always involved in trauma of any consequence. Thorough examination is therefore important in order to arrive at a correct anatomic diagnosis. Acute traumatic arthritis is a collective term applied to various injuries which are described separately below.

1. *Acute Traumatic Synovitis.* This lesion is descriptive of the reaction of the joint itself to injury and consists of the development of *swelling, pain, limitation of motion, and muscular spasm* (Fig. 12). The same reaction occurs to a lesser extent when normal joints, immobilized for many weeks, are first used, especially if the alignment of an associated fracture has been faulty or other structural defects are still present. The same signs are seen in the early hours of an infection. Fluid in the joint cavity (hydrops, hydroarthrosis) is one of the first signs of synovitis and is manifested clinically in the superficial *joints by swelling, by obliteration of the normal bony landmarks*, and by a sense of fluctuation on palpation. In the knee, the fluid lifts the patella from its normal contact with the femur (floating patella) which can often be shown by pressing it against the femur, producing an audible or palpable click. In the hip and shoulder these signs may be obscured by the overlying muscle; comparison with the opposite side may be helpful.

Aspiration of the joint is the surest and sometimes the only way of detecting fluid in the synovial cavity and also reveals the kind of fluid present. If it is blood, proof of hemorrhage is obtained. Investigation of the fluid microscopically and bacteriologically is often useful and important. Removal of blood decreases the danger of limitation of motion from incomplete absorption and organization of blood clots. Aspiration of fluid may also *serve a therapeutic purpose* in relieving the pain and swelling. Pain, however (in the absence of fracture or sprain), is not apt to be severe. When pain is intense, there is usually an associated lesion of bone, ligament, or tendon which is ordinarily detectable by local tenderness. Limitation of motion is usually due to pain and associated *muscle spasm*, but it is also due in part to fluid in the joint. Muscle spasm is a protective reaction which serves to splint the injured part and is prominent in many joint diseases, both acute and chronic. It is sometimes elicited only on movement.

Injuries to bone and cartilage must be excluded before definitive therapy since they

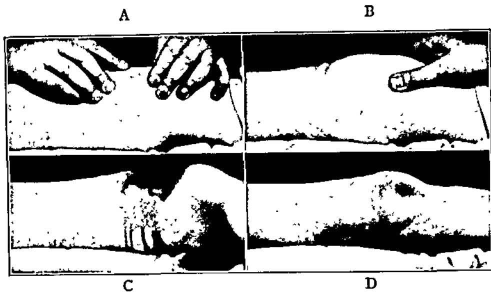


Fig. 12. Acute traumatic synovitis. The patient, a 70-year-old man, was struck by a motorcycle. A, the method of demonstrating a patellar click; the index finger of the right hand presses the "floating patella" against the femur. B, note the obliteration of the normal bony landmarks of the knee joint by the fluid contained within the joint; the examining fingers detect a definite sense of fluctuation. C, aspiration of the joint; nearly 100 ml. of bloody fluid was obtained. The blood pointed to joint damage and an x-ray revealed a tiny but definite fracture into the joint without displacement. D, after aspiration; note the normal contour of the knee.

may demand special treatment. The key to the spontaneous recovery of simple acute traumatic synovitis is the resorption of the fluid which ordinarily takes but a few days and indicates a subsidence of the inflammatory process. During this time, rest and firm bandaging of the joint are advisable. As soon as the pain subsides, voluntary motion is started, but weight-bearing is best postponed for at least a week or two. Cold, in general, limits edema due to trauma when applied early (in the first hour or two) though heat, by promoting the circulation, aids in its resorption once swelling develops. Cold or heat may be used for the relief of pain depending to some extent on the preference of the patient.

2. *Laceration of Joint Capsule.* The treatment of lacerations involving the joint capsule is, in reality, the same as that of any deep wound as already discussed in Chapter 14. If the injury is recent, and exploration and débridement are indicated, the wound is treated thoroughly, the joint cavity carefully inspected and irrigated, then the joint capsule *closed without drainage.* If 24 hours or more have elapsed since injury, and infection is already present, conservative measures, such as immobilization, cleanliness, and perhaps traction, are indicated; insertion of drains into cavities is as a rule to be condemned. Chemotherapy is most useful in preventing as well as in combating infection.

3. *Rupture of Ligaments* (*Sprain*). Sprains are to be suspected in every severe injury about the joint, especially if there is excruciating tenderness over the ligaments and not over the bone. Severe pain which develops on specific motions only also suggests a sprain if a fracture is not present. Detailed consideration of sprains will be found in Chapters 22 and 23.

4. *Injury to Articular Cartilage.* At the time of injury it is sometimes impossible to detect evidence of trauma to cartilage which may only become apparent later because chronic joint disability develops. When a fracture extends into a joint, as shown by x-ray, the joint cartilage is obviously injured and aspiration of the fluid in the joint will be bloody. Severe injuries of this type may be treated by suspension and traction or immobilization in a plaster cast, even if there is no displacement of fragments. Early motion

is also advisable. Treatment of any associated fracture is obviously important.

Injury to the semilunar cartilage of the knee is of a special type and may consist of rupture or tearing with or without dislocation. Injury to the semilunar cartilage frequently follows a severe sprain because of the intimate attachments of this cartilage to the joint capsule and ligaments. The internal semilunar cartilage is most commonly involved, especially following any severe twisting and abduction of the knee, such as catching the foot in a hole while running. The injury may consist of a detachment, tear, or crush. Sometimes the medial portion of the medial meniscus is displaced into the intercondylar notch, the so-called "bucket handle" type of lesion. If the cartilage is displaced, complete extension may be impossible and the usual local signs of acute injury will develop with severe pain and local tenderness. "Locking" of the knee with inability to extend the joint is a frequent manifestation. Occasionally, considerable clear, straw-colored fluid accumulates in the joint. Replacement often occurs spontaneously or may sometimes be achieved by careful flexion and rotation of the tibia, with or without anesthesia. Success is shown by the ability to completely extend the leg. The knee is then treated like acute synovitis except that in severe cases immobilization in plaster may be necessary. If, after six weeks of nonoperative therapy, symptoms persist, especially pain and instability, the damaged cartilage should be removed although operation should not be postponed over a year after the injury. Rupture of the *cruciate ligaments* of the knee sometimes occurs and is to be suspected when abnormal mobility in the anteroposterior direction is elicited. This is generally associated with tears of the medial collateral ligament. If such an injury is seen early and recognized, then surgical repair of the torn medial ligament should be carried out. Repair of the cruciate ligament is a complicated procedure and is not advised in the acute phase of the injury. Following surgical repair, immobilization in plaster is indicated for a period of three to four weeks, following which intensive exercises are necessary to strengthen the quadriceps muscle. When the indications are not sufficient to justify operation, then immobilization should be employed.

5. *Chronic Joint Lesions.* Acute injuries to joints and cartilage are sometimes followed by such lesions as chronic synovitis, chronic traumatic arthritis, and joint mice. (*a*) *Chronic synovitis* is an ill-defined term applied to recurrent and persistent pain, swelling and fluid in the joint, particularly after exertion. When chronic synovitis develops after trivial injury, tuberculous disease of the joint is to be suspected. Often it follows trauma with injury to cartilage or because of malunion of an associated fracture. Occasionally an unsuspected joint mouse is responsible. In many cases, the cause is to be sought in repeated trauma or perhaps in insidious types of infection. Villous arthritis is a form of chronic synovitis in which the synovia proliferates to form numerous projections or villi into the joint. It may develop spontaneously without previous injury, is most common in older individuals, and may be present without symptoms or at most may cause "rheumatic" pains. It is manifested clinically by puffiness about the joint, commonly the knee, and a crepitation on motion and sometimes by fluid in the joint. (*b*) *Traumatic arthritis* is really a type of synovitis as just discussed except that the symptoms of pain, swelling, and disability clearly follow, and are due to a preceding injury (see also p. 540), and are aggravated by use of the part. (*c*) *Joint mice* are loose bodies in the joint which are composed of fragments of cartilage or bone which becomes covered with cartilage, and which move freely about inside the joint cavity (Fig. 13). They may give rise to pain, swelling, and disability (often in attacks) by their mechanical interference with joint movements. They are frequently the result of previous joint disease or injury. Loose bodies in the joints are also produced by spontaneous detachment of segments of the articular cartilage and underlying bone (osteochondritis dissecans) or by actual neoplastic growths from the synovial membrane (osteochondromatosis). X-ray usually reveals these loose fragments when they contain bone or calcified areas. Operation for their removal is often indicated when symptoms are sufficiently severe.



Fig. 13. Joint mouse of unusually large size in the knee. The patient was a 67-year-old man. Symptoms of mild pain in the knee were not sufficient to justify arthrotomy. There was no history of trauma.

Joint Infections. *The effect of pathogenic bacteria on joints is varied and depends on the causative organism. Since all parts of the joints are usually affected, the lesion is really an arthritis.* The influence of chemotherapy as discussed above (under Bone) is also true of joints.

1. *Acute Pyogenic (Suppurative) Arthritis.* The joint is not infrequently infected with pyogenic bacteria from without by penetrating wounds, from adjacent osteomyelitis, or most commonly *from the blood stream* as a *hematogenous infection.* In the latter case, evidence of disease elsewhere—such as a pneumonia, endocarditis, otitis media, and septicemia—is frequently present. However, the joint involvement may be the first manifestation and occasionally the only site of disease. Like osteomyelitis, the disease is most commonly encountered during childhood. The streptococcus, staphylococcus, and occasionally the pneumococcus are the organisms most frequently responsible for the infection. The gonococcus produces a special type of arthritis, which is considered separately. The inflammation begins as an acute synovitis, the joint filling with thin, slightly turbid fluid which contains many bacteria and leukocytes of the polymorphonuclear type. As the infection progresses, the cellular elements increase so that after a few days frank pus may fill the joint cavity. Of serious importance is the early involvement of the cartilage, which is attacked directly and destroyed. On some occasions, the loss of cartilage may include most of the articular surface. Pressure of the opposing surfaces aids in destruction of cartilage. As the inflammation subsides, these denuded areas become filled with granulation tissue and, since this cartilage does not regenerate, the raw areas eventually become united with each other across the more or less obliterated joint space with either fibrous or bony tissue. This end stage of repair leaves the joint in a state of immobility or ankylosis which, if bony, results in absolute immobility, but if fibrous may be only partial (Fig. 14).

Clinical manifestations are local and general, the latter being those of septicemia, as already described. The degree of fever and prostration may be great and often overshadows the local lesion. Pain is exquisite and localized to the joint, but is especially excruciating on the slightest attempt to move the joint. Tenderness is also marked and is sometimes so pronounced that the weight of the bedclothes cannot be borne. Associated with



Fig. 14. Complete ankylosis of the knee due to suppurative arthritis. X-rays (anteroposterior and lateral views) taken six months after the onset; the infection has completely subsided. The patient, a healthy 18-year-old schoolboy, was treated conservatively in a hospital for several weeks; late in the course of the infection several abscesses were opened above the knee, extensions no doubt of pus breaking through the suprapatellar bursas. Note the complete bony ankylosis; an arthroplasty was done with partial restoration of motion.

the pain is extreme muscle spasm of the adjoining muscle groups which splint the joint in a fixed position, usually in slight flexion. In the hip, flexion is accompanied by abduction and external rotation, a position which corresponds to the greatest relaxation of the joint capsule. Swelling, heat, and hyperemia are localized to the region of the joint. In superficial joints, the swelling is characteristically confined to the joint cavity which is easily apparent because of the obliteration of the bony landmarks. Frequently there is also a prominent superficial swelling due to edema of the subcutaneous tissue overlying the joint. Aspiration is important, especially in the deeper joints, such as the shoulder and hip, in order to establish the existence of joint fluid. Moreover, the examination of such fluid by smear and culture is essential for final diagnosis. Smears may reveal the presence of the organisms; segmented leukocytes also tend to brand the lesion as an acute pyogenic infection. Roentgenologic changes are late and due to destruction of cartilage obliterating the normal clear area between the ends of the bone.

Differential diagnosis of suppurative arthritis from acute rheumatic fever, acute osteomyelitis, and acute cellulitis is important because of the difference in the type of treatment required. *Acute rheumatic fever* is accompanied by acute joint manifestations for which operation is contraindicated; the joints are usually involved several at a time in this disease (but in a shifting pattern), and the general reaction, while marked, is not as severe as in acute pyogenic arthritis; the presence of cardiac signs and symptoms and the more subacute nature of the disease are also helpful. *Acute osteomyelitis* does not cause much joint tenderness or muscle spasm; there is no joint fluid or swelling; limitation of motion is less pronounced; the tenderness, while close to the joint, is located distinctly over the bone. *Acute cellulitis* over the joint may be confusing, but it is important to recognize since mechanical trauma, especially incision or even aspiration, may be

harmful. Usually the superficial location of the redness and swelling accompanying cellulitis is so localized as to be characteristic. Red streaks (acute lymphangitis), when present, point to acute cellulitis since they are absent in the deeper infections. Similarly, regional lymphadenitis, which practically always accompanies acute cellulitis, is absent in infections of the bone or joint, at least in its early stages. The typical joint effusion is absent in acute cellulitis; muscle spasm and limitation of movements are not apt to be present.

Treatment of acute pyogenic arthritis has been greatly influenced by the introduction of chemotherapy, which has permitted excellent healing without the necessity of operation in many patients whose treatment can be started early in the course of the disease. Antibiotics are used systematically as well as locally. The infected fluid is removed from the joint cavity and replaced with a solution of penicillin. This is repeated every day or two until the infection has subsided. Protection of the joint in a splint is appreciated by the patient to guard against movement, which is very painful. Slight traction with Buck's extension also relieves pain considerably and minimizes necrosis of the cartilaginous surface of the bones.

Now that antibiotics are available, arthrotomy is not necessary except in the rare, neglected cases when actual pus is found at aspiration or if suppuration develops in spite of treatment. Before the days of chemotherapy it was the procedure of choice. If considerable destruction of cartilage has occurred and ankylosis is inevitable, it is important to assure a good position for the fixed joint, i.e., one which gives a maximum of usefulness and a minimum of disability (see p. 551). Months or years after the infection has subsided, motion in the ankylosed joint may be restored by various types of arthroplasty.

2. *Gonococcal Arthritis.* There is usually a history of an acute urethritis or cervicitis preceding the joint lesion by several weeks. Because of modern therapy, the disease is only rarely seen now. While several joints may seem affected at the onset, serious manifestations generally localize in only one (Fig. 15). The disease is thus usually monoarticular, involving, in order of frequency, the



Fig. 15. Gonococcal arthritis of the elbow. A mild case with spontaneous recovery in a 26-year-old male. Onset two weeks previously; aspiration revealed thin serosanguinous fluid from which the gonococci were grown *in pure culture.* Patient discharged three weeks later with full function. This condition is no longer common.

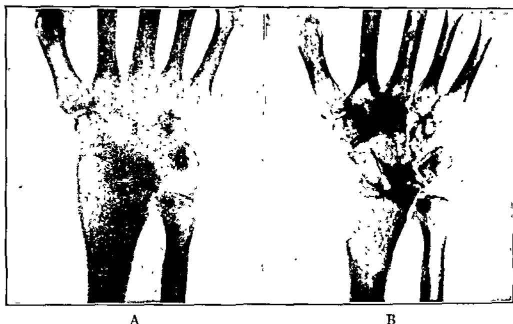


Fig. 16. Gonococcal arthritis of the wrist. The patient was a 27-year-old woman. There was a definite history of genital infection with identification of the organism from the cervix. A, x-ray seven weeks after onset of pain and swelling which was severe and disabling. Note the obliteration of joint markings indicating destruction of cartilage. Two periods of artificial fever each of four and one-half hours' duration produced prompt and lasting relief of symptoms; B, x-ray four months later; note the bony ankylosis, especially between the radius and lunate bone. The patient, while free from pain and swelling, has a partial limitation of motion. (Courtesy, Dr. Peter Heinbecker.)

knee, wrist, elbow, shoulder, hip, and ankle. Constitutional reaction is confined to fever and leukocytosis; prostration is rare. Tenderness and pain over the joint are exquisite so that sometimes even jarring of the bed is feared by the patient. However, great variations in severity are encountered, from a simple serous synovitis to actual suppuration with destruction of cartilage. In the former instance, satisfactory restoration of joint function may be expected; in the latter, bony or fibrous ankylosis is the rule (Fig. 16). The course of the disease may be prolonged for many weeks before subsidence of the acute manifestations. It may be difficult in the early stages to determine the course of the infection. This inconsistency in the progress of the disease undoubtedly accounts for the wide diversity in method of treatment. In many cases, especially the milder types, nonoperative therapy is adequate. However, in the suppurative type, incision and drainage may be indicated. Most forms of treatment used previously, such as fever therapy, have now been displaced by chemotherapy, especially with penicillin, as in other forms of gonorrheal infection, including salpingitis, and the like. Of great importance in cases ending in bony ankylosis is final fixation in a useful position of the joint (see p. 551).

3. *Tuberculous Arthritis.* This lesion is not uncommon in childhood and is a frequent cause of disability and crippling (Fig. 17). While constitutional signs and symptoms, such as loss of weight and afternoon fever, may be present, the disease not infrequently seems to present only local manifestations in a joint. Whether the bone or joint is the primary point of infection in joint tuuberculosis is still a considerably disputed question. A "cold abscess" occurs late in joint tuberculosis, but an effusion into the synovial cavity is usually present, which is often called "white swelling" because of the absence of acute signs. The hip and knee are commonly affected, but the ankle, shoulder, and elbow are also often involved. Years ago, before the days of dairy inspection and pasteurization, tuberculosis of bones and joints was much more common and was usually of bovine origin.

The onset is often gradual and insidious. Pain is always present, but may be slight, and is often referred to another joint. Thus the

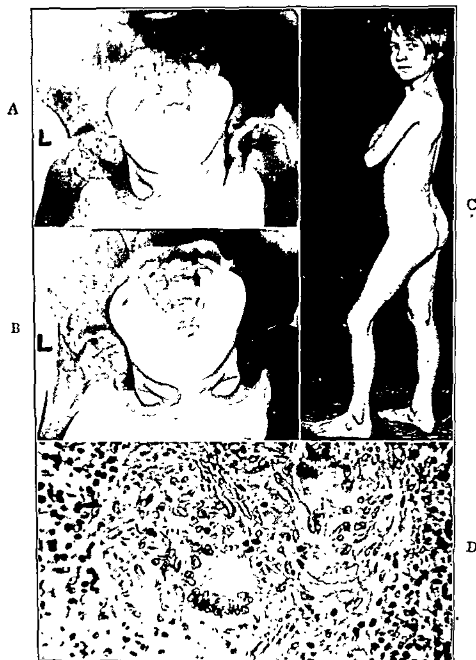


Fig. 17. Tuberculosis of the hip. For several months the patient, a seven-year-old girl, complained of pain and stiffness in the left hip followed by an increasing limp. A, the x-ray at this time was negative; nevertheless an operation was performed and a biopsy of the capsule revealed tuberculous tissue on microscopic section. The joint was immobilized in a cast; B, x-ray, one year later, shows marked changes and beginning ankylosis; C, photograph on admission; note the flexion at the hip and atrophy of the calf on the affected side; D, photomicrograph of the biopsy specimen showing typical giant cells.

pain associated with tuberculosis of the hip is often referred to the knee. Limping, however, may be the first apparent symptom. In the superficial joints, swelling is nearly always apparent. Aspiration will reveal fluid. There is a gradual atrophy of the adjacent muscles, which are tense and spastic. At night when they relax the pain may become severe and give rise to "night cries." After the disease has been present for some time, marked atrophy of bone becomes apparent. Eventually deformity may develop as a result of the

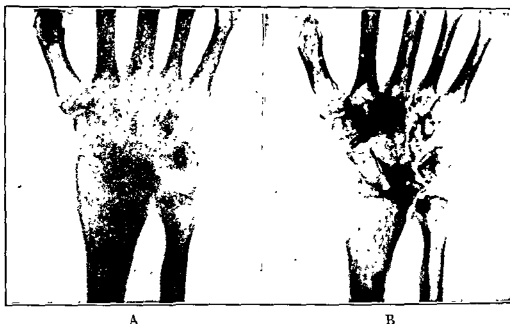


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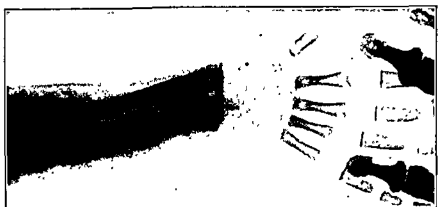


Fig. 18. Syphilitic osteochondritis. The patient was a Negro infant, three weeks old. Note the increased density along the epiphyseal line. The term "syphilitic epiphysitis" is often applied to the disease. The term "pseudoparalysis" is sometimes used because of the disability produced. The name of Parrott is also associated with this lesion. Although only one wrist is shown in the above photograph the same appearance was noted on the opposite side and in both lower extremities. The mother noted a swelling of the infant's wrists which were painful and tender; a history of a fall was suspected. The Wassermann was strongly positive and after two antiluetic treatments the pain and swelling disappeared.

This defect in the vertebra is known as spondyloschisis, and this is now thought more likely to be on the basis of posture than a congenital abnormality, as emphasized by Rowe and Roche (11). Clinical manifestations include pain and weakness in the lower back and inability to bend forward. Examination reveals a striking lordosis; diagnosis is aided by lateral roentgenograms to show the characteristic displacement and oblique films to show the presence of a spondyloschisis. Initial management should consist of a stout lumbosacral corset, a fracture board for sleeping, and instructions to the patient on how to protect the low back. When such conservative measures fail to give satisfactory relief of symptoms, spinal fusion frequently must be resorted to in order to stabilize the involved area. Resection of the neural arch, particularly in those individuals

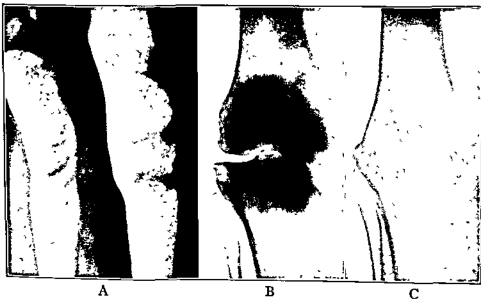


Fig. 19. Charcot joint. The patient was a tabetic, aged 57. A, note the enlargement of the left knee which was almost a "flail" joint, i e., movable in all directions without sufficient stability to avoid disability; B, anteroposterior x-ray of the joint; C, x-ray four months after arthrodesis, showing bony union between tibia and femur.

destructive process and/or dislocation. If drainage of a cold abscess is established, either spontaneously or by incision, the resultant sinus may drain for months or years. Because of the paucity of early clinical manifestations, diagnosis is often difficult but is aided by the following procedures: (*a*) tests to rule out other evidence of tuberculous disease—such as the tuberculin test, x-ray studies of the lungs, and examination of the genitourinary tract and urine—should be carried out. Also important is examination of the sputum; if there is no sputum, gastric lavage should be done to determine whether tubercle bacilli may have been swallowed in sputum coughed up from the lungs. (*b*) X-ray is negative early in the disease, but later shows generalized bone atrophy as compared with the opposite side and an irregular fuzzy appearance with ill-defined joint outlines. Destructive bone changes are seen only in the more advanced cases. In the spine, a lateral view will show erosion of the vertebral bodies and destruction of intervertebral discs. Characteristic of bone tuberculosis is the absence of new bone formation in the x-ray; in this respect it differs from pyogenic infections and syphilis. (*c*) The joint fluid may yield growth of tubercle bacilli on culture, or may produce the disease after injection into a guinea pig. It rarely shows bacilli on smear. (*d*) Arthrotomy with biopsy of the synovia may be the most reliable method of diagnosis. This may be justified in order to start therapy as early as possible. In attempting to establish the diagnosis in the hip in young children, biopsy of the deep inguinal lymph nodes may be helpful, as pointed out by Mercer (10).

In treatment, medicinal therapy is now very important. Since the development of the antituberculosis drugs—such as streptomycin, azoniazyd, and para-amino salicylic acid —great progress has been made in combating tuberculous infection. This progress applies not only to generalized disease but also to joint lesions. Great importance is, therefore, attached to a long-continued program of therapy with these drugs (6 to 12 months) as well as to prolonged immobilization of the diseased joint. Generally, streptomycin is administered intramuscularly two or three times a week in association with one of the other two drugs given by mouth. Under the protection of these drugs, it is possible to incise and clean out abscesses followed by primary healing and also to eradicate tuberculous foci by direct surgical attack without complication. If joint tuberculosis is diagnosed in the incipient stage before joint damage has occurred, and the patient is treated persistently with these drugs, and the joint protected by abstinence from weight-bearing, it is possible to anticipate recovery with preservation of joint function. In most cases of joint tuberculosis, damage to the joint is too far advanced to permit functional recovery, and arthrodesis of the joint is the best treatment. This procedure should be delayed until inactivation of the disease has been obtained by chemotherapy. Ankylosis of a joint in optimum functional fashion produces very little disability, and most patients can work and even participate in many sports. In Pott's disease, spinal fusion is practically always necessary and may be performed earlier than in the case of other joints because it is a completely extra-articular procedure.

4. *Syphilitic Arthritis.* Two forms are described; one is the osteochondritis of infancy, which is sometimes the first evidence of congenital syphilis (Fig. 18). A history of trauma is not infrequent and the joint is swollen and tender and clinically simulates an injury or an acute infection. The x-ray shows characteristic changes in the epiphysis; the Wassermann reaction is positive. The lesion responds to chemotherapy, though immobilization is necessary for symptomatic relief of pain. The second form of syphilitic arthritis is the painful joint encountered in the secondary stage and is often confused with tuberculosis. The Wassermann reaction is helpful. Treatment is also medical (chemotherapy). Charcot joints (Fig. 19), though of syphilitic origin, are discussed on page 550 under the heading of neurotrophic joints.

Spondylolisthesis. This lesion consists of a forward displacement of the body of one of the lumbar vertebra on the ones beneath; the most common is the fifth, which slips forward over the sacrum. One of the causes is a defect in the pars interarticularis, which allows the body to slip forward while the posterior element remains in its normal position.

ticularly in the hands and feet, become a cause of annoyance and must be removed surgically.

2. Hemophilics often have chronic stiffness and enlargement which may resemble a tuberculous joint. The swelling is due to the presence of blood which, on organization, gives rise to fibrous ankylosis. The history is important since the disease is hereditary, transmitted by females, but present only in males. Treatment is largely of a prophylactic nature. Transfusions are useful and endocrine therapy has been recommended. An antihemophilia fraction of the plasma proteins has been isolated and is easier to give than blood.

3. Hysteria is a term of exclusion used in joint disease when thorough examination is negative in a patient with stiffness and limp which, however, are characteristically varible. Contracture may develop from disuse. There may be a history of injury. Diagnosis is important, but often difficult. The finding of a psychogenic factor may help. Treatment requires careful local treatment and psychotherapy.

4. Intermittent hydrops is similar to chronic synovitis except that it is not connected with injury or activity, is not painful, and comes and goes without apparent cause. It may be of vasomotor nature (Allison). Treatment is symptomatic.

Congenital Deformities. The most important ones are clubfoot and congenital dislocation of the hip. *Clubfoot* is a congenital deformity due to maldevelopment of the bones and joints of the foot. The most common type of deformity is talipes equinovarus or reel foot, though other varieties are seen (talipes varus, valgus, equinus, and calcaneovalgus). The disease may be unilateral or bilateral. Treatment in early cases consists of manipulation and application of a plaster cast. Open operation is necessary in some patients when, after trial, conservative measures fail. *Congenital dislocation of the hip* is a not infrequent disease and, though present at birth, usually remains undiagnosed until the child begins to walk, when an abnormal gait or limp is observed. The condition is often allowed to progress into later childhood, during which the disability becomes more marked and the anatomic changes more pronounced. Diagnosis is confirmed by roentgenograms which show an abnormally shaped and displaced head of the femur and a deficient acetabulum. The disease may be unilateral or bilateral. Treatment consists of reduction by manipulation or open operation and immobilization by plaster cast. The method depends on the age of the patient and the experience of the surgeon. The best results are obtained when the condition is recognized and treatment is started before the age of one year. Today, with greater awareness on the part of pediatrician, cases are being diagnosed and treated even before the age of six months.

Ankylosis of Joints. Ankylosis is a frequent outcome of previous joint disease. As already mentioned, it occurs after destructive arthritis and tuberculosis. A severe fracture into the joint which involves both articular cartilages may result in bony union across the articular surfaces with complete joint immobility. In the operation of arthrodesis such a bony ankylosis is purposely produced. In all such cases, the degree of the resulting disability is minimized to a great extent if the joint is fixed in a favorable position and angle. It is important, therefore, that, whenever possible, healing be allowed to take place with the joint fixed in such a position. If the position is poor and ankylosis has not yet taken place, the joint should be manipulated under anesthesia, followed by immobilization at the proper angle in a plaster cast.

The angle of maximum usefulness is different for each joint as follows: ankle, at right angles with just enough equinus to permit wearing of a shoe with a heel; knee, in slight flexion to clear the ground easily when walking; hip, in moderate (15 degree) flexion and abduction for the same purpose; wrist, in partial dorsiflexion to aid in the grip of the fingers (Fig. 20); elbow, in flexion at an angle of 135 degrees, provided that the opposite elbow is normal and allows the hand to be brought to the face, with the forearm pronated enabling the hand to be used in most types of work; shoulder, at about 40 degrees abduction and 15 degrees flexion to enable as extensive motion of the scapula as possible, and to permit the hand to reach the mouth easily.

who have significant degrees of sciatica associated with their spondylolisthesis, may be helpful.

Arthritis Deformans. This term used to be applied indiscriminately to all forms of rheumatism and arthritis but, as the result of advances in the last 25 years, a great many different types of arthritic disease have been sorted out from this large wastebasket, have been classified, and their individual characteristics described. The following represents a somewhat simplified classification modified from that prepared by the New York Rheumatism Association (Hinch P. S., et al. Smith, Ninth Rheumatism Review: Am. Int. Med. 28:66, 1948).

A. Infectious arthritis of proven etiology
B. Possible infectious etiology unproven
  1. Arthritis of rheumatic fever
  2. Rheumatoid arthritis (atrophic, chronic infectious)
    a. Adult type
    b. Juvenile type (Still's disease)
    c. Ankylosing spondylitis (Marie Strumpell, etc.)
    d. Psoriatic arthritis
  3. Arthritis associated with various infections
C. Degenerative joint disease
  1. Osteoarthritis (hypertrophic, degenerative)
    a. Generalized
    b. Localized
      (1) Secondary to previous trauma
      (2) Secondary to joint abnormality
D. Arthritis associated with disturbance of metabolism
  1. Gout
  2. Others
E. Arthritis of neuropathic origin
F. Neoplasms of joints
G. Mechanical derangements of joints
  1. Traumatic arthritis
  2. Joint disturbance secondary to abnormal postural strain
H. Miscellaneous forms
  1. Manifestations of systemic disease
    a. Arthritis of serum sickness
    b. Arthritis of hemophilia
    c. Intermittent hydrarthrosis
    d. Pulmonary osteoarthropathy
    e. Hysteric joints
  2. Local joint disturbances
    a. Aseptic bone necrosis
      (1) Secondary to contusion, fracture, dislocation, or air embolism
      (2) Of unknown etiology (juvenile osteochondrosis of different bones and locations)
    b. Osteochondritis dissecans
    c. Osteochondromatosis

It is not possible in a textbook of surgery to discuss all these diseases and the student should consult the standard textbooks of medicine or the fifth revised edition of Comroe's Arthritis by Hollander (12) and collaborators, already mentioned. Pathologically, the disease exhibits hypertrophic forms in which there is proliferation of the fibrocartilage outside the joint (Heberden's nodes) as well as fibrous tissue and bone; in other cases, the joints become atrophic or ankylosed. Although various bacteria from time to time have been isolated from the joints of these cases, the cause is still undetermined. One group is called Still's disease and occurs largely in childhood. Further discussion of the various types of the disease and their treatment may be found in medical and orthopedic monographs on the subject.

Neurotrophic Joints. This term is applied to the so-called Charcot joint which occurs as a manifestation of tertiary syphilis, but may be seen in other diseases of the spinal cord, such as syringomyelia, or rarely in peripheral affections of the sensory nerves as in diabetes mellitus. It is a slowly developing, painless, degenerative lesion, although the manifestations may seem to appear acutely. Especially characteristic are the hypertrophic changes which most frequently attack the knee, but also the ankle, foot, hip, spine, shoulder, and elbow. When seen in the upper extremity, syringomyelia is more likely to be the etiologic factor. The earliest sign may be periarticular edema, but in the late stages the swelling, which is due to degenerated collapsing bone and overgrown fibrous tissue and cartilage, may be enormous. Pain is absent; instability of the joint is the usual complaint. Treatment may be conservative, i.e., support of the insecure joint by appliances if possible, or operative, i.e., resection of diseased tissue and production of a bony ankylosis.

Other Joint Diseases. 1. Gout is due to the deposition of sodium urate around joints (and also in the cartilage of the ear) as tophi. It is most frequent in joints of the great toe and causes episodes of severe pain and disability with relief of symptoms between attacks. Treatment is generally medical and dietetic, but occasionally tophus deposits, par-

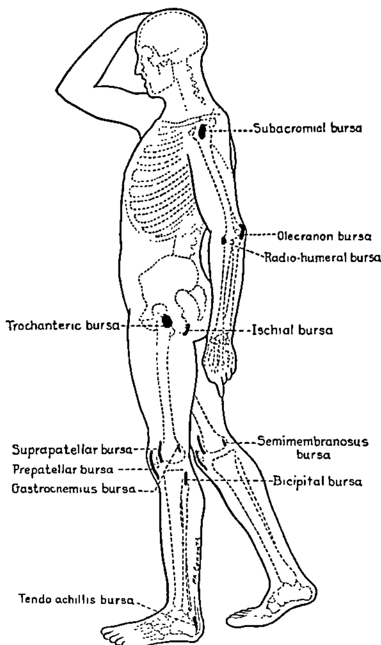


Fig. 21. The sites of the more common bursas.

Chronic Bursitis. This may follow an acute lesion, but frequently develops insidiously and is often erroneously diagnosed as neuritis, "rheumatism," or chronic arthritis. The pathologic changes in the bursa are similar to those in the joint, in that fluid is present and villous overgrowth of the bursal lining occurs. In addition, however, calcification of the wall of the bursa is not infrequent and can often be seen in a roentgenogram. Symptoms are pain, more or less severe, brought about or aggravated by certain movements which tend to compress or irritate the bursa. Tenderness is often localized to this area. Swelling may develop because of effusion which is always present, and may be demonstrated by aspiration. Treatment is often dramatically successful following the injection into the bursa of hydrocortisone with Novocain. For single attacks, even in calcified bursa, this often suffices. Occasionally it is necessary to recommend that the occupation or activities

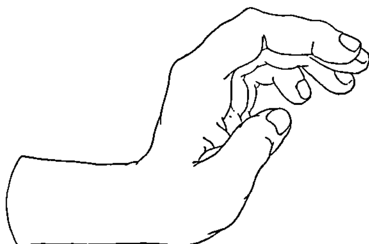


Fig. 20. Dorsiflexion. Slight dorsiflexion (less marked than that shown) is the most favorable position in ankylosis of the wrist; this gives satisfactory function with a useful grasp to all of the fingers and thumb.

BURSAS

Bursas are similar to joints in that they are cavities lined by modified fibrous tissue or mesothelium which secrete a mucoid lubricant and thus enable tendons or muscles which lie over them to glide smoothly against underlying bone or other structures. In superficial locations, the bursa protects underlying structures from trauma inflicted over them. Bursas likewise serve to facilitate skeletal movement. Some of them are present consistently at certain points; others may form in response to special needs when certain movements are repeatedly used, or when there is pressure over a bony prominence as, for example, with a bunion. Some bursas are not closed cavities but, like those about the knee, continuous with the joint cavity. They are similar to joints in their reaction to injury; they develop an effusion or swelling, may become painful and cause disability. Unlike a joint, however, a bursa may be destroyed or excised without causing disability, but often replaces itself by regeneration from neighboring connective tissue. Bursas are only rarely the site of an acute pyogenic infection; the most common lesions follow trauma which is sometimes direct and acute, but more often is the result of repeated slight injuries or continual external pressure.

Acute Traumatic Bursitis. This lesion may follow direct blows, but more often it results from the same type of forceful movement which gives rise to ruptured tendons or ligaments. These structures often form the floor or roof of bursas so that injury to them directly implicates the bursa. After such an injury, the differential diagnosis may be quite difficult and often impossible. A knowledge of the exact location of the various bursas is invaluable (Fig. 21). Often, acute bursitis develops rather suddenly, manifestations appearing after a relatively slight injury, repeated previous insults, or irritations to the bursa. Thus, a housemaid may injure her prepatellar bursa each time she scrubs the floor on her hands and knees but have no acute symptoms until, suddenly, an acute exacerbation follows some slight blow. Symptoms are local pain and swelling, the former aggravated by certain motions and the latter apparent only in the superficial bursas. Disability is usually quite severe on account of the pain, limitation of motion, and muscle spasm. Occasionally, infection develops in the bursa and progresses to suppuration, thereby demanding drainage by incision. Treatment of traumatic bursitis consists of rest in a comfortable position and local applications of heat until motion is possible without pain. The acute process may last for a week or two and subside without further difficulty. The injection of hydrocortisone into the bursa is often effective (see below). Unfortunately, further attacks are liable to occur. More troublesome is the development of more or less constant or chronic disability and pain.

The diagnosis is made on the demonstration of marked limitation of motion, pain in forcing motion in any direction, and on a negative x-ray examination.

Treatment requires restoration of motion by gradual and gentle active exercises. Formerly, forceful manipulation of the shoulder to rupture the adhesions under anesthesia was often done, but such complications as fracture of the humerus and dislocation of the shoulder were common and gentler methods are now in vogue. The patient is generally started with pendulum exercises with the body flexed at the hips and the arm hanging down like a bell clapper. These exercises should be carried out three or four times a day and combined with application of heat. Local injections of Novocain and hydrocortisone at weekly intervals are helpful. Pain at night is a frequent complaint, and it may be well to bandage the arm to the side in a sling to give relief. Sedatives are generally necessary. Progress is slow over several months and much patience and encouragement are necessary. In the end, most of these patients recover completely.

The *olecranon bursa* lies between the skin and the olecranon. Bursitis (miner's elbow) occurs at this point because of frequent injuries sustained over the bursa. The disease, however, is by no means confined to miners. Excision of the bursa is often indicated, when symptoms of pain and disability are sufficiently severe.

The *radiohumeral bursa* lies over the radiohumeral joint between the extensor carpi radialis and the supinator brevis muscles. Bursitis (tennis elbow) develops because the bursa is irritated by forceful movements of the elbow and wrist, associated with pronation and supination of the forearm. Local tenderness over and above the head of the radius is pronounced. The pain may be severe and disabling in some instances. It may be necessary to differentiate radiohumeral bursitis from myositis or epicondylitis involving the attachments of the extensor muscle group at the lateral epicondyle, which may cause similar symptoms. In both conditions, the injection of hydrocortisone into the tender area often gives relief. In intractable cases, the use of a cock-up wrist splint for a period of one to two months, to prevent tension on the extensor muscles of the wrist, will generally bring about a cure.

The *prepatellar bursa* is not as commonly injured in present days of mechanical appliances and machines for scrubbing floors. It is a superficial bursa lying between the patella and the skin or between the proximal end of the tibia and skin where irritation occurs from kneeling position (housemaid's knee). Rest and cessation of repeated injuries usually results in relief of symptons.

The *Achilles bursa* which lies between the gastrocnemius tendon and the os calcis is frequently the seat of inflammation and is commonly caused by improperly fitting shoes. Relief usually follows removal of the cause; only rarely is operation indicated.

The *ischial bursa* may be the seat of inflammation (weaver's bottom) in individuals who maintain the sitting position for long periods because the bursa lies between the ischial tuberosity and the overlying gluteal muscles.

TENDONS

Many but not all tendons move in sheaths which are structurally similar to joints and bursas but, in general, are not frequent sites of serious disease. Wounds, tumors, and acute infections of tendons have been described in previous chapters.

Traumatic tenosynovitis is a common, but rarely serious injury which produces an inflammation of the sheath with outpouring of an excess amount of the lubricating fluid. Local tenderness is present along the course of the sheath and use of the tendon produces pain. There may be palpable a creaking or crepitation on motion of the tendon. Later, fibrous tissue may replace the fluid and fibrin, thereby resulting in limitation of motion. In general, rest should be maintained as long as acute symptoms are present, but increasing active motion should follow as soon as subsidence of pain permits.

Other lesions depend on special injuries. *Rupture* of the biceps tendon, the tendon of Achilles, and of the extensors of the thumb and fingers produces characteristic manifestations which readily are recognized and treated. A dislocation of a tendon into a new abnormal site usually involves the long head of the biceps, the peroneal tendons, and the

of the patient be changed in cases due to irritation from certain specific muscular movements. In other patients, the decision as to the advisability of motion or rest is not an easy one. The application of penetrating heat is usually helpful. Excision of the bursa is often indicated and frequently curative, especially when the bursa is calcified and has not responded to nonoperative treatment (13, 14).

Specific Types of Bursitis. Although there are about 26 bursas in the human body, discussion will be limited to the few which are commonly diseased.

The subdeltoid (*subacromial*) bursa is located over the tuberosity of the humerus, underlying the acromion process and the deltoid muscle. Part of its floor is formed by the rotator cuff (chiefly made up of the supraspinatus and infraspinatus tendons). Its function is to permit the tuberosity to glide under the acromion and deltoid in movements of abduction and rotation of the shoulder. This bursa is commonly implicated by one of the following lesions: (*a*) calcifying tendonitis, (*b*) rupture of the rotator cuff, and (*c*) adhesive tendonitis.

(*a*) *Calcifying tendonitis* is caused by deposition of calcium salts in the tendinous tissue of the rotator cuff. The cause of this is not known, but it is thought to be due to degenerative changes induced perhaps by friction, and in some cases by trauma. Calcium is deposited in cicatricial tissue low in blood supply. The deposits are, in the beginning, chalky and granular, but later they tend to coalesce and become puttylike. They generally lie in the floor of the bursa where they cause pain when pinched by movement under the acromion. In some cases they may rupture into the bursa and cause an acute inflammatory reaction.

In the subacute stage, pain is caused by movements of abduction and rotation of the shoulder; in the acute stage, pain is exquisite on the slightest movement, and the clinical picture may resemble that of acute pyogenic arthritis.

Diagnosis is based on demonstration of local tenderness over the tuberosity by the production of pain on abduction and rotation of the shoulder, by limitation of motion, and by x-ray examination which demonstrates the calcium deposit.

Treatment is most successful when the calcium can be aspirated or washed out through two needles with salt solution. When the deposit is granular and diffuse, this is not possible, and other measures must be used. Some advocate x-ray therapy, others ultrasonic treatments, and others diathermy. Injection of hydrocortisone locally is often helpful, but may have to be repeated several times at weekly intervals. Most dramatic results are often obtained by aspiration and injection of hydrocortisone in the acute cases. In recurrent cases, when it has been impossible to get rid of the deposit by other means, it is necessary to open the bursa surgically and curette out the calcified mass.

(*b*) *Rupture of the rotator cuff* is caused generally either by a fall on the outstretched arm or by lifting effort of the shoulder. The injury results in pain due to hemorrhage into the bursa and shoulder joint, and also to inflammatory reaction. The examination reveals local tenderness and notable weakening or loss of abductor power, depending upon the extent of the lesion. X-ray examination is generally negative. When the diagnosis is doubtful, confirmation can be obtained by the injection of radio-contrast fluid into the bursa or shoulder joint following which x-ray examination will reveal direct communication between the bursa and the joint. Treatment, as in other types of tendon rupture, requires open surgical repair of the torn structure. Early diagnosis is important because the sooner the operation is carried out, the better are the results.

(*c*) *Adhesive tendonitis* is a condition in which adhesions develop between the rotator cuff and the adjacent structures, including the joint capsule, and the long tendon of the biceps both in the bicipital groove and in its intraarticular course. The bursal structure is often implicated. Two factors are generally present in varying degree; first, degenerative changes in some of the anatomic structures mentioned previously, and second, decreased use of the shoulder due to pain. The condition often follows a Colles' fracture or an attack of coronary thrombosis in which conditions the shoulder is kept in the adducted position for long periods on account of pain.



Fig. 22. Photograph of both hands and forearms showing a Volkmann's contracture on the left side, approximately three years after onset. (From Hill and Brooks. Ann. Surg.)

inability to move the fingers, and (*e*) tingling and numbness of the fingers. When the condition complicates fractures about the elbow the damage is presumably done by continued swelling after immobilization of the joint in flexion or damage to the brachial artery or veins. As a consequence, the venous return from the forearm is shut off. The arteries for a time continue to pump blood into the forearm, thus increasing the swelling which ultimately obstructs the arterial supply to some extent. It is important to realize that after six or seven hours the damage is done and no form of treatment will bring the muscles back to normal. The end result is the conversion of the contractile muscle fibers to fibrous tissue which produces an atrophied forearm and useless clawhand (main en griffe). The reader is also referred to the excellent article by Seddon (15).

Treatment is prophylactic, except when the swelling is due to vascular injury. In this case, the only efficient form of treatment is prompt and radical incision of the fascia overlying the tense tissues and inspection of the brachial artery. The greatest danger exists from swelling about joints immobilized with a cast or appliance in a flexed position. This is apt to occur most frequently after fractures about the elbow. After reduction and immobilization of such fractures, the surgeon must palpate the radial pulse since its absence is a sign of serious vascular obstruction. The patient should be either kept under observation for 24 hours or emphatically instructed to return at the first indication of severe pain, numbness, or paralysis of the parts distal to the lesion. In such an event, the constricting dressing or cast must be loosened or removed even at the expense of losing the position of the fracture.

Myositis ossificans is a remarkable post-traumatic condition in which osseous tissue develops in muscle. It may occur in hematomas of the muscle or may develop in muscles adjacent to a fracture. Tendons are oc-

posterior tibial tendon. Treatment consists of operative replacement of the tendon and rest for a week or two until movements without pain are possible. *Stenosing tenovaginitis* (trigger finger, snapping finger) is a lesion which produces a temporary impediment of flexion (or extension) of the finger which, on further movement, suddenly gives way and the finger snaps. Stenosing tenovaginitis of the radial styloid (de Quervain's disease) is common and is a painful condition involving the abductor pollicis longus tendon.

Tuberculous tenosynovitis manifests itself as a thickening of the tendon sheath which becomes filled with thick fluid and caseous material containing "rice bodies." The flexor and extensor tendons of the wrist, hand, and forearm are most commonly involved. Treatment may be nonoperative or surgical. At operation, all excessive tissue is removed and the wound closed carefully without drainage. A prolonged course of antituberculosis drugs should then be instituted.

MUSCLE

Unlike bone and joints, muscle is seldom the site of disease or serious injury, except by direct penetrating trauma. Involvement of muscle by war wounds is of great importance and is discussed on page 107. Of all the elements important to movement and locomotion, muscle is the most prone to atrophy, especially of disuse. Paralysis results from denervation; recovery depends on regeneration of the nerve.

Atrophy. There are several types of atrophy. Disuse alone, particularly following immobilization or when associated with ankylosis, will produce a rapid and severe muscular atrophy. The presence of infection aggravates the process. However, atrophy of disuse alone is usually relieved rapidly as soon as active motion is restored and leads, in most cases, to the return of the muscle to its normal state. Frequently, the stronger set of muscles contracts and results in a deformity, often called contracture, which is especially apt to follow atrophy due to paralysis of the muscles which follows interference with the nerve supply. Spontaneous subluxation (dislocation) of the joint may thus occur. Atrophy from severance of the nerve supply produces a paralysis as well as atrophy and is much more serious because recovery depends on regeneration of the nerve (see p. 615). Disease of the brain and spinal cord may also produce muscular atrophy; the paralysis which results is flaccid or spastic. *Cerebral palsy*, i.e., spastic paralysis of children (Little's disease) is produced by cortical injury sustained during childbirth, or to prenatal or perinatal cerebral defects. Mental deficiency to lesser or greater degree may accompany the muscular paralysis. Treatment is a complex neurological and orthopedic problem. *Poliomyelitis* is a serious cause of muscle atrophy which becomes permanent when the infection destroys the anterior horn cells which innervate the muscles. With the onset of paralysis it is very important that deformities be prevented and that a program of bracing and muscle re-education be carried out. The permanent paralysis is frequently accompanied by deformity due to the pull of the uninvolved muscles. The treatment of these deformities is an orthopedic problem and consists of muscle training, braces of various types, transplantation of tendons, and, if necessary, arthrodesis of the joints that are responsible for the deformity. A rare type of atrophy is *progressive muscular atrophy*, which is a slow chronic disease begining in the intrinsic muscles of the hand. *Birth (Erb's) paralysis* affects the muscles of the upper extremity and is due to injury to the brachial plexus during delivery. The diagnosis should be made as soon after birth as possible. Treatment consists of immobilization and relaxation of the injured structures; operative treatment of the nerves is only occasionally indicated.

Volkmann's contracture (ischemic contracture or paralysis) is a tragic and often preventable accident which occurs most frequently following a supracondylar fracture of the humerus or a fracture of the bones of the forearm (Fig. 22). It is caused by interruption of the circulation to the distal part of the extremity, either arterial injury or venous interruption. Soft tissue injury alone with extensive extravasation of blood about the elbow or forearm may also be the instigating factor. The first symptoms are (*a*) diffuse pain in the forearm and hand, (*b*) cyanosis, especially of the fingers, (*c*) swelling, (*d*)

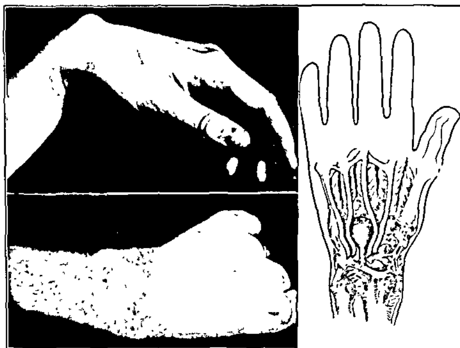


Fig. 24. Ganglion of the wrist. The patient was an 18-year-old school girl. Note in the photograph how the tumor is made more prominent by flexion at the wrist; it was tense but definitely cystic on palpation. The patient complained of constant rheumatic pain in the wrist and arm, aggravated by use. The sketch was based on a drawing made at operation and shows the mass attached to the joint capsule; it contained thick mucoid fluid. Excision of the entire cyst including its pedicle was performed; complete relief ensued.

ing mesothelial cells or to mucoid degeneration of the fibrous tissue. Its origin as a herniation of the joint or tendon sheath, a theory which is generally held, lacks definite proof. Clinical manifestations beside the presence of the tumor include pain or "rheumatoid" discomfort which may result in definite disability. Treatment, to be curative, necessitates complete excision, or recurrence may follow. Breaking the cyst with a well-directed blow is sometimes followed by cure. Aspiration and injection of sclerosing solutions has been used, but is obviously dangerous, especially if the lumen of the ganglion communicates with the joint cavity.

Corn or *clavus is a local hypertrophy of the* hornified layer of the skin which develops as a response to chronic pressure or irritation, usually from tight or ill-fitting shoes. The most important clinical manifestation is severe pain which is due to pressure over the lesion and can be relieved by shifting the contact with the shoe from the corn to the surrounding skin by means of a circular pad with a hole in the center, which protects the tumor. This is the principle upon which corn plasters are used. Eradication of the lesion *may be achieved by elimination of the source* of the chronic irritation or by actual excision. Occasionally, certain types of corns (particularly those between the toes) can be cured only by removal of the underlying bony prominence. Corns occasionally are the site of infection which is treated by the usual methods.

Hallux valgus is a common deformity of the great toe (outward deflection or abduction) which to a great extent, at least, is caused by wearing ill-fitting, short, and pointed shoes (Fig. 25). Its importance lies in the frequent *formation of a bunion which is often painful* and disabling. This knob or bunion consists of an overgrowth of the medial margin of the distal end of the metatarsal bone at the metatarsophalangeal joint *and is associated with* a true bursal sac which contains fluid and often becomes infected. Relief of pain is often achieved by correcting the normal position of the toe with an appliance, and the wearing of correct shoes. In severe cases, operation



Fig. 23. Congenital torticollis. The patient was a 12-year-old girl. Note the attitude and the tense sternomastoid muscle on the patient's right. This muscle was cut across and a cast applied; the result was excellent six months later. X-ray showed only a rotation of the cervical spine. (Washington U. Clinics.)

casionally affected also. Treatment consists of prolonged and complete immobilization; in a good many instances, partial or complete absorption of the bone in the muscle occurs. Occasionally, surgical removal of mature myositis ossificans is indicated.

Wryneck (*torticollis*) is a disfiguring disease of the cervical muscles (or their motor nerve supply) in which, by continuous muscular contraction, the head is maintained in a rotated and inclined position (Fig. 23). The condition develops generally in infants soon after birth. It is due to fibrous contracture of the sternocleidomastoid muscle. The exact cause is unknown, although there are various theories. An acquired type, often called spasmodic torticollis, occurs in adults and belongs to the group of nervous disorders known as "tics." When prolonged, torticollis produces changes in the cervical spine. Treatment of the congenital type is operative and manipulative and should be instituted as early in life as possible.

MISCELLANEOUS LESIONS

Ingrown toenail, a common lesion, especially in young women, is a frequent cause of suppuration about the large toe as described previously. Although with rest, elevation, and local heat, such an acute infection diminishes or subsides, it is apt to recur unless the ingrowing part of the nail finally clears the soft tissue of the toe or is removed and prevented from reforming by an appropriate operation. Tight shoes and too frequent clipping of nails probably do play some role in the development of this lesion. More important, however, is the presence of a congenital abnormality in the root of the nail allowing the lateral edge of the nail to grow out obliquely or downward and penetrate the soft tissue. This produces pain and frequently breaks the skin, thus introducing infection which persists because the ingrown nail acts as a foreign body.

Treatment in mild cases consists of excising a v-shaped wedge of the central portion of the nail, or of shaving the central surface from the distal edge back to the cuticle to relieve the lateral pressure and to encourage growth toward the center to such an extent as to relieve symptoms. Radical treatment consists of removal of a lateral or medial segment of nail, including its root, so completely that the removed portion will not regenerate. A simpler procedure, and usually as effective is the excision of a wedge of the hypertrophied toe adjacent to the ingrown nail (Winograd, 1929). Operation is done under local anesthesia with the aid of a rubber tourniquet.

Ganglion is a term applied to a smooth, rounded mass (0.5 to 1.5 cm. in diameter) which commonly appears in the distal portion of the wrist on the dorsal surface, and is made more prominent by flexion of the wrist (Fig. 24). It also occurs on the ventral or lateral surface of the wrist and around other joints, particularly the knee. It is found in women much more frequently than in men (3:1) and is especially common in young women. The tumor, when exposed, is found to lie among the tendons, but nearly always is attached to the joint capsule. It consists of a fibrous sac which contains mucoid material. The lumen of the cyst is commonly a closed cavity, but occasionally it communicates with the wrist joint or a tendon sheath. As to its pathogenesis, the most careful studies have shown that it originates from the fibrous tissue of the joint capsule as a small, benign, fibrous neoplasm. The cystic nature of the tumor is explained by the presence of secret-



Fig. 26. Dupuytren's contracture. The photograph indicates the maximum possible extension. Disability was insufficient to justify operation. The patient was a 45-year-old male.

tarsal scaphoid, which is most frequently the bone involved in the strain (Key and Conwell, 16). Occasionally adequate support to a low arch will relieve symptoms.

Scoliosis, or lateral curvature of the spine, is a disfiguring but not necessarily crippling deformity in which the spine develops more or less fixed lateral curves with rotary components (Fig. 27). It may result from congenital malformation of the vertebrae, or from poliomyelitis with imbalance of the spinal or abdominal muscles, or from other diseases of the central nervous system. The most common form, called "idiopathic" because of unknown etiology, develops during the growing period. Most curvatures tend to increase with growth but become arrested and static when skeletal maturity is achieved.

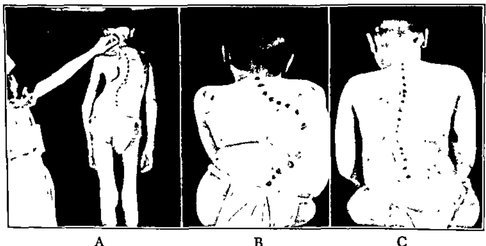


Fig. 27. Two types of scoliosis. A, idiopathic scoliosis with marked rotation of vertebral bodies. This type of scoliosis is very difficult to treat; B, total curvature of the spine without rotation due to infantile paralysis. No rotation of vertebral bodies. This type of curve is easily corrected and held by spine fusion; C, same as B, after fusion of the spine (Courtesy, Dr. C. H. Crego, Jr., Shriners Hospital for Crippled Children, St. Louis.)



Fig. 25. Hallux valgus before and after radical operation for its correction. The bunion and the *proximal two thirds of the first* phalanx of the toe were excised and the toe immobilized in its normal position. (St. Louis City Hospital.)

consists of removal of the bursa and trimming off the excess bone, thus allowing the toe to assume its normal position.

A *callus* sometimes forms under the ball of the foot at the points of pressure exerted by the heads of the metatarsals. Appliances to take pressure off the painful point will often be effective as will a "metatarsal bar" fitted into the shoe for the same purpose. Such calluses may become infected and simulate a perforating ulcer (mal perforans). However, the x-ray shows no osteomyelitis. The treatment consists of paring away the hypertrophied skin until the bottom of the sinus is reached. The adequate drainage of the tiny abscess thus achieved will result in healing.

Dupuytren's contracture is a rare, probably hereditary disease and of gradual and insidious onset (Fig. 26). This condition is not a contracture of the tendons but of the palmar fascia on the ulnar side of the palm, gradually causing a flexion deformity of the fifth and later the fourth finger. The fascia extending into the fingers, as well as the overlying skin, may also be involved. There is no pain or tenderness, disability being due to inability to extend the fingers. Treatment consists in the careful surgical excision of the hypertrophied bands of fibrous tissue. This is generally carried out through multiple small incisions corresponding to the palmar creases. Extension of the flexed fingers is obtained by dissection and removal of the hypertrophied bands. In extreme cases, it may be necessary to amputate an extremely flexed digit in order to improve function of the hand.

Foot strain is encountered under a variety of circumstances which bring the patient to the surgeon, largely because of foot pain, which may be severe or mild, and may be accompanied by swelling and other anatomic changes. Frequently no definite organic basis can be made out. Foot strain is a common disease, and is often aggravated by the wearing of improperly fitting shoes. It should be emphasized that the form of the arch has nothing to do with the painful symptoms of foot strain. The diagnosis and treatment of foot strain is largely an orthopedic problem; rest of the strained ligaments plays an important part in therapy, especially by the use of a Thomas heel, which gives support to the

pressure on the metatarsal head, but if the pain persists surgical removal of the neuroma is indicated.

Hammer toe is an acquired flexion deformity of the toes, most often the middle ones, due usually to tight fitting shoes. Severe cases may require a plastic operation (wedge resection of the interphalangeal joint).

Calcaneal spurs are sometimes the cause of pain localized to the heel (painful heel, policeman's heel). The pain may be due to an associated bursitis but is apparently primarily dependent upon the presence of the spur, which may be unilateral or bilateral. Diagnosis is readily made by the x-ray. If pain is very severe, and does not respond to conservative treatment, excision is justifiable.

Ainhum is a rare degenerative disease consisting of a circular constriction at the base of the toes, usually the little toe; it occurs largely in African countries but is encountered in this country in Negroes only. The etiology is unknown. The toe finally drops off; there is no effective treatment (Fig. 28).

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Curvature of the spine causes little functional disturbance except in poliomyelitis where muscular instability necessitates spinal fusion, generally after correction of the curve. In other cases, the chief problem is that of disfigurement; when this reaches a stage that threatens to impair the prospects of a happy life, corrective treatment in a hinged plaster jacket furnished with a turnbuckle, followed by spinal fusion, should be considered. While braces and corrective exercises have been advocated in the past, it is doubtful whether these accomplish worthwhile results either in arresting progress of the curvature or in diminishing its extent.

Athlete's foot (epidermophytosis) is really a dermatitis of the skin of the foot, especially in and between the toes, caused by a fungus infection. Manifestation of cellulitis and suppuration may occur whenever secondary pyogenic invasion occurs; treatment is the same as that of infection in general. Eradication of the original ringworm may be achieved by cleanliness, and by the use of a nonirritating fungicide (resorcinol lotion, Whitfield's ointment, and the like). Infections about the feet, in general, may largely be prevented by ordinary cleanliness, as well as the wearing of properly fitting shoes; this is particularly important in patients suffering from peripheral circulatory disease and diabetes.

Foreign bodies, usually needles, are not infrequently introduced (accidentally) beneath the skin, especially in the hand, and often produce pain and disability, particularly if located over an area which is subject to trauma. Removal of the foreign body is usually indicated. When the needle is deeply seated, its removal may be difficult. The x-ray film should be taken just before operation inasmuch as considerable migration of the foreign body may occur even in a day or two. X-ray localization is often aided by placing a lead marker at a convenient point on the skin. Obviously two views are essential. If infection is present, the treatment is the same as that of an infected wound, as has already been described. An electronic device to aid in localizing metallic bodies may be helpful during operation.

Metatarsalgia (Morton's disease) consists of severe pain below and between the heads of the metatarsal bones, probably produced by pressure or impingement of the nerves between the heads of the metatarsal bones. Most commonly it is due to the development of a neuroma at the bifurcation of the digital nerves from the plantar nerve. Conservative treatment consists of rest and elimination of

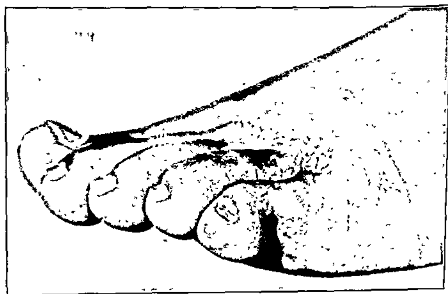


Fig. 28. Ainhum. The constriction at the base of the toe was first noted five years previously and has steadily progressed. The patient, a 35-year-old Negro, complained only of mild pain of three weeks' duration, due to a superficial infection which responded to local incision and bed rest. The remnants of the infection can be seen in the scaling of the skin.

lesions with this common basic malformation may be located in various regions of the body and may present a variety of clinical pictures. Numerous terms have been utilized in the past to denote this condition, e.g., pulsating venous aneurysm, arteriovenous varices, racemose aneurysm, angioma arteriole, arterial varices, and hemangiectatic hypertrophy of a limb. When these lesions occur on the scalp they have commonly been referred to as cirsoid aneurysms.

In the embryonic stage a vessel may function both as an artery and as a vein, and multitudinous communications may exist between arteries and veins. It is not surprising, therefore, that these congenital arteriovenous communications may persist beyond fetal life and occur in mature individuals. Trauma and infection have been cited as causes of the appearance and rapid growth of these lesions.

The condition occurs most commonly in the head and neck and secondly in the extremities. There are usually multiple arteriovenous communications between the smaller arteries and veins, in contrast to the acquired arteriovenous fistulas which are generally single and are found in larger vessels. Although not all are invariably present, the following characteristics have been noted of the typical congenital arteriovenous fistula: 1. pulsating compressible tumor; 2. enlarged tortuous afferent arteries; 3. systolic thrill and bruit over the tumor, or the afferent arteries or both; 4. enlarged tortuous efferent veins; 5. discoloration, resembling the so-called port-wine stain, in the overlying or surrounding skin; and 6. increased local skin temperature. Other effects, such as cardiomegaly, hypertrophy of the involved limb, and slowing of the pulse on compression of the artery, may or may not be present; their presence is generally related to the volume of blood being shunted through the arteriovenous fistulas.

The various clinical types of congenital arteriovenous fistulas have been grouped by Flynn and Mulder into three types.

Type I. Single or Multiple Gross Congenital Arteriovenous Fistulas. This type is the rarest of all. The arteriovenous communications occur between major arteries and veins, e.g., between the carotid artery and jugular vein, as in the case reported by Reinhoff (2), and may be treated successfully by direct ligation of the fistulas.

Type II. Extensive, Minute, Congenital Arteriovenous Fistulas. This type occurs more frequently. The communications are usually microscopic in size, and although numerous, they are difficult if not impossible to identify. Anatomically, they occur in the smaller distal branches of the arterial tree. Cases of this type (Fig. 1) generally have extensive involvement of an entire or a major portion of an extremity, frequently with gross hypertrophy and with marked superficial arterial and venous dilatation. There is at present no generally accepted method of treatment other than amputation, when indicated,

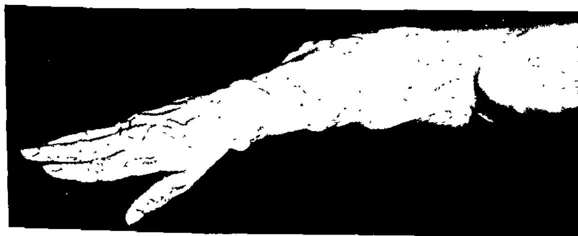


Fig. 1. Extensive minute congenital arteriovenous fistulas (Type II) involving forearm and arm of 28-year-old woman. Dilated veins and increase of size of hand and arm noted for many years. No history of trauma. Severe pains in fingers and ulceration of finger tips. Amputation subsequently required.

25

BLOOD VESSELS

William P. Longmire, Jr., and Jack A. Cannon

Early vascular surgery was related almost exclusively to the control of bleeding from traumatically severed or damaged blood vessels. The reintroduction of the ligature (first described by Celsus) by the French surgeon, Ambrose Paré, was the major contribution of this period. Later interest in the treatment of aneurysms and arteriovenous fistulas broadened the objectives of surgery of blood vessels from the mere arrest of hemorrhage to the correction of abnormalities of the vessels themselves and of the pathways of blood flow. The ligation technics of Antyllus and John Hunter for arteriovenous fistulas and the proximal ligation procedures for arterial aneurysms as practiced by Halsted were extensions of the use of ligatures in the treatment of diseases of the vascular system.

The direct suture of blood vessels was first utilized for the cure of an arterial aneurysm by Matas in his technic of endo-aneurysmorrhaphy. The introduction by Leriche and Adson of surgical procedures designed to alter the well-established influence of the autonomic nervous system on the caliber of the peripheral arteries and arterioles opened a new phase of vascular surgery.

In recent years, the early experimental technics and ideas of Carrel of direct vascular suture and the use of vascular grafts to reestablish circulation in traumatized and locally diseased vessels have seen wide application in clinical surgery. Thromboendarterectomy as first proposed by dos Santos has also been widely used.

ARTERIAL ANOMALIES

Abnormalities of the arteries are extremely common and consist chiefly of *malposition.* Common examples of significance in operative surgery consist of abnormalities in position of the hepatic and cystic arteries. When the former vessel is anomalously placed anteriorly, it may be injured or be mistaken for the cystic artery and erroneously ligated during cholecystectomy; this error gives rise to pathologic changes, resulting in hepatic insufficiency, and may well be fatal if the condition is not promptly recognized and the patient treated vigorously with antibiotics. Anomalies of the renal artery, particularly aberrant vessels, are not uncommon; they tend to give rise to symptoms, as the aberrant vessels may press on the ureters or pelvis of the kidney and produce obstruction with consequent infection.

Other abnormalities may be considered *structural* in type. The most commonly encountered example being the various types of hemangiomas. These are discussed in Chapter 20. Far less frequent are the congenital arteriovenous fistulas which, despite their rarity, deserve comment because they must be clearly differentiated from acquired arteriovenous fistulas in matters pertaining to diagnosis, treatment, and prognosis.

Flynn and Mulder (1) define congenital *arteriovenous fistulas* as all nontraumatic vascular abnormalities in which arterial blood passes into the venous system without going through a capillary bed. Congenital vascular

and systemic evidence of blood loss. Blood lost from an injured artery may pass directly into an adjacent opening in an accompanying vein and establish an arteriovenous fistula. The characteristic thrill and to-and-fro bruit may be absent at the time of initial examination but they will be present within a few hours when a normal arterial pressure is reestablished and the arterial spasm diminishes. In injuries to vessels of an extremity, there will usually be evidence of impaired circulation to the involved limb with loss of or diminished pulse and absent or diminished blood pressure.

Impaired circulation due to contusion of an artery may be difficult to differentiate from mere arterial spasm. With contusion, however, the impairment is more severe and persistent and is accompanied by signs of muscle, nerve, and skin ischemia—such as pain, paralyses, pallor, and coolness. Vascular occlusion due to spasm rarely persists to the point of causing distal pain and paralyses. If necessary, a regional block of the sympathetic nervous system by an injection of procaine will abolish arterial spasm and differentiate the two conditions.

TREATMENT. First-aid treatment has as its objective the control of blood loss without causing further injury until definitive treatment can be instituted. Active bleeding from a wound, even one involving an injury to a major artery, can, in most instances, be controlled by direct pressure over the bleeding area. In an extremity, this can be accomplished by placing padded gauze over the wound with a snug circular bandage. Elevation of the extremity aids in the arrest of hemorrhage. When bleeding is not controlled by compression, a hemostat may be carefully applied directly to exposed large vessels. A tourniquet should be used only for life-endangering hemorrhage not controllable by other means. It should be placed as low on the limb as possible and should be sufficiently tight to control arterial bleeding and not merely to produce venous obstruction and increase bleeding. Once a tourniquet has been applied, it should be remembered that it may be fatal to loosen it after massive hemorrhage until lost blood volume has been replaced. Major arterial injuries in the base of the neck, axilla, chest, abdomen, or groin can be treated adequately only in an operating room. Bleeding from iliac or common femoral vessels may be retarded by firm compression of the abdominal aorta against the spine.

If hemorrhage has been severe, blood volume should be restored as quickly as possible by transfusions. Other intravenous solutions, such as saline, glucose, or dextran, may suffice temporarily until blood is available. In every major arterial injury, the goal should be complete restoration of circulation through the damaged vessel. Various circumstances may at times thwart this goal, such as lack of proper facilities, unavoidable delay before treatment is instituted, or other life-endangering injuries of higher priority. Incised or divided arteries are treated by freshening the edges of the vessel and suturing the edges or ends of the vessel with fine silk suture on small-gauge atraumatic needles. Local heparinization is used to prevent thrombosis and every effort is taken to prevent infection of the wound. When segmental excision of a major vessel in a limb has occurred, it may be replaced with a plastic prosthesis or an autologous vein graft. The vein graft probably has the greater chance of remaining patent, but it may be subject to future aneurysmal dilatation. Larger vessels, such as the aorta or iliac vessels, may be replaced with arterial homografts or plastic prostheses as described on page 556. If the excised area is short, sufficient vessel length may be obtained for a direct end-to-end suture by wide dissection of the proximal and distal ends of the vessel, by rerouting the vessel, or by flexing the extremity.

If contusion of an artery is sufficient to produce persistent arterial occlusion, the traumatized area should be explored and an effort made to re-establish circulation by removing a thrombus at the site of injury. Should this procedure be unsuccessful, the vessel may be ligated proximally in an uninjured area. The contused area may be excised, if proper facilities are available, and the vessel anastomosed end-to-end, or the area may be replaced with a graft. When such procedures are attempted, it is essential that all of the damaged arterial wall be excised and the suture performed in a portion of the vessel that has a normal wall.

False Aneurysm. When a hematoma forms in the soft tissues following an incision or

because of ulceration, bleeding, or pain of the involved part.

Type III. Localized, Minute, Congenital Arteriovenous Fistulas. This is the most frequently encountered type. It is a more discrete lesion which generally occurs in the peripheral portion of an extremity or about the head or neck. The external ear is a frequent site for this type of lesion. Treatment is directed toward: 1. reduction of the afferent arterial supply by ligation of regional arteries; and 2. total or partial excision of the discrete lesion. Satisfactory results are usually achieved.

ARTERIAL TRAUMA

Acute Injury. One of the most exciting advances in surgical technic in recent years has been in the management of acute vascular trauma. Even under battlefield conditions, as was demonstrated in the Korean War, successful attempts have been made to preserve circulation in major vessels of the extremities by restorative vascular procedures rather than by ligation of the injured vessel (3). The employment of such procedures requires special skills and facilities as well as surgical judgment in the proper selection of cases, but the possibilities of such technics should be known and appreciated by everyone (4, 5, 6). Acute trauma to a vessel may take the form of incision, division, segmental excision, or contusion.

Any manipulation of or trauma to an artery will result in contraction of the wall of the vessel and dimunition of its diameter due to the contraction of the circular muscular fibers in the vessel wall. Such constriction in an incised or lacerated vessel which is only partially divided will diminish blood loss because the lumen of the vessel proximal and distal to the point of injury will become narrow. The opening in the vessel itself in the incised or partially divided artery, on the other hand, is actually enlarged and stretched open by this contraction resulting in continued loss of blood. Complete division of the vessel, however, permits vascular contraction to exert its complete protective power. The lumen of the vessel is maximally constricted, and the ends retract into the surrounding soft tissue. As the blood pressure falls, clotting about the end of the vessel is encouraged and the loss of blood stopped. In experimental animals, under identical conditions, blood loss from a partially divided artery is greater than from a completely severed vessel. Clinically, the total amount of blood lost under these two circumstances (i.e., partial division or complete division) will vary greatly depending largely upon other conditions of the wound—such as size, location, depth of vessels in the wound, and extent of the partial laceration in the vessel wall. The injury in which excision of a segment of an artery occurs is similar to complete division of the vessel but is generally more serious, inasmuch as there is usually greater associated injury to surrounding soft tissues, bone, other vessels, and nerves.

A high velocity missile passing in close proximity to an artery, a fractured bone, or a blunt force which compresses an artery against an adjacent bone, may result in *contusion* of the vessel of such magnitude as to interrupt the flow of blood without actually interrupting the continuity of the vessel. This type of injury is associated with disruption of the vessel wall and progressive formation of an intramural hematoma, which may enlarge sufficiently to occlude the vessel completely or to slow the flow of blood sufficiently to permit formation of an additional intraluminal thrombus.

Diagnosis. Any injury which occurs in the region of major vascular channels should immediately raise the suspicion of arterial injury. Evidence of external bleeding may or may not be present. If an artery has been incised or divided, there will be bleeding, either (*a*) externally; (*b*) into the soft tissues between fascial planes; (*c*) into a space or potential space, i.e., lumen of the bowel, bladder, or peritoneal cavity; or (*d*) into a simultaneously injured vein. External bleeding, of course, may readily be detected. A hematoma from extravasated blood in soft tissues can be detected by palpation although, if the wound is not examined soon after injury, generalized edema of the area may be difficult to differentiate from a hematoma. A pulsating hematoma is indicative of an arterial injury. Concealed hemorrhage into the lumen of the alimentary tract, pleura, or peritoneal cavities must be diagnosed on the suspicion of arterial injury plus local signs of blood in these spaces

pulse volume, blood pressure, or oscillometric determinations, is impaired.

The patient complains of pain in the region of the aneurysm from compression and irritation of adjacent nerves. When the peripheral circulation is compromised, there is intermittent claudication or resting pain due to ischemia of distal muscles. The usual course of the false aneurysm is one of gradual enlargement with increasing pain and discomfort. Rupture and exsanguination may occur in neglected cases.

Treatment is directed toward evacuation or excision of the aneurysmal sac and repair of the opening in the artery. The involved artery is isolated and occluded above and below the site of the aneurysm. The sac is then dissected out or opened and evacuated, and the opening in the artery is closed with fine silk sutures. If the vessel has been sufficiently damaged, excision and grafting of the involved area may be the indicated procedure.

Arteriovenous Fistula. The congenital type of arteriovenous fistula has been described previously. The traumatic variety follows a stab or small-caliber missile wound which lacerates both the artery and its accompanying vein. A hematoma forms about the vessels, external bleeding stops, and within the confined area of the hematoma the arterial blood finds its way back into the vein. Within a short time this channel becomes endothelialized, and a permanent arteriovenous communication is established. If the openings in the vein and artery are immediately adjacent to one another, they may become sealed together without the formation of an aneurysmal sac. On the other hand, if the hematoma has been large and the vascular openings not immediately contiguous, a large aneurysmal sac is formed. Vascular injuries of this type have been reported following surgical trauma: i.e., after the use of transfixion suture, at the superior pole of the thyroid during thyroidectomy, and in the broad ligament during hysterectomy. A number of vascular lesions of this type have occurred following injury to the terminal aorta and inferior vena cava or the iliac vessels during the removal of a ruptured nucleus pulposus.

The examination of any fresh wound suspected of involving major vascular structures should include careful palpation for the continuous thrill and auscultation for the continuous murmur characteristic of an arteriovenous fistula.

Manifestations. The signs and symptoms of this abnormal vascular communication, which develops days or weeks later, if it has been overlooked on the initial examination or early treatment has not been undertaken, will be related to the size of the communication, the volume of blood flowing through the fistula, its location, and the presence or absence of an aneurysmal sac. The patient may be aware of a pulsating mass in the region, and there may be local pain due to compression of adjacent nerves. If vessels in the neck or head are involved, the patient frequently complains of a buzzing noise in the head.

On inspection, dilated superficial veins are present, and a pulsating mass may or may not be visible. The area is warm, and a continuous thrill may be felt over the fistula. On ausculation a continuous murmur is present. Circulation distal to the fistula is usually impaired with a reduction of skin temperature, diminished or absent pulses, and in long-standing cases actual muscle atrophy and skin ulceration. A small communication in major vessels or a fistula involving smaller vessels such as the radial, dorsalis pedis, or superior thyroid arteries rarely produce any symptoms other than these local findings.

If the fistula is of sufficient size to shunt a large quantity of blood from the arterial directly into the venous circulation, there is a profound effect on the circulatory system. Blood volume and cardiac output are increased, the heart increases in size as the left ventricle dilates and hypertrophies, and acute heart failure with pulmonary edema may occur. Pressure over the area sufficient to interrupt the passage of blood through the fistula will cause a prompt bradycardia. This is called the Branham-Nicoladoni sign.

Treatment. Up until a few years ago, procedures were not often used that permitted closure of the fistula and re-establishment of circulation through the involved artery. The generally recommended surgical treatment was ligation of all vessels communicating with the sac, and ligation of the artery and vein above and below the fistula, followed by excision or obliteration of the aneurysmal sac. Circulation peripheral to this point was there-

laceration of an artery, the area may become sealed off, the external bleeding cease, and, over a period of time, a fibrous capsule will encircle the hematoma. If the opening in the vessel remains patent, there is a constant flow of blood into and out of the area of the hematoma. Laminated areas of clotted blood of varying thickness line the periphery of such a space, the interior surface becomes endothelialized, and the center is filled with fresh flowing blood from the artery. The entire mass pulsates with each cardiac systole. This is called a *false aneurysm,* for in contradistinction to a true aneurysm, which is surrounded by all, or a part of the wall of the vessel from which it originates, the false aneurysm has no true wall other than the layer of fibrous tissue which forms within the soft tissue space (Fig. 2).

The majority of such lesions are traumatic in origin resulting from a stab wound or a small missile, although at times a vessel with syphilitic or atherosclerotic changes may rupture spontaneously and form a false aneurysm.

The *diagnosis* is usually not difficult. As stated, there is usually a history of local injury. A mass can be palpated. The degree of pulsation will vary depending on the amount and tenseness of the overlying soft tissue and the thickness of the laminated clot. A systolic thrill may or may not be palpable but a systolic bruit is always heard over the mass. The bruit is present only during systole and is quite different from the to-and-fro murmur associated with an arteriovenous aneurysm. The vessel of origin is compressed by the mass and peripheral circulation, as determined by

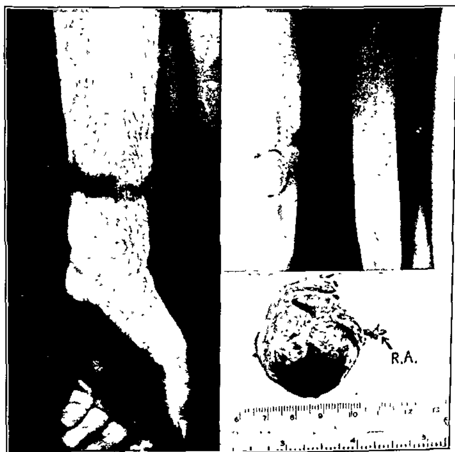


Fig. 2. Traumatic aneurysm secondary to an injury six years previously. A small fragment of steel penetrated the forearm, but healing was rapid without any special treatment. A small mass developed shortly after injury; a few weeks before entry it began to enlarge rapidly, aided perhaps by the development of an essential hypertension. The photograph was taken just before operation. The x-ray on the right shows the foreign body lying adjacent the radius, and calcification in the wall of the aneurysm. Below is a photograph of the aneurysmal sac after removal. The proximal end of the radial artery (R.A.), is indicated.

its further progress. Thus, most emboli lodge at a bifurcation of the common iliac, the femoral, or popliteal vessels. Less frequently, the embolus is detained at a point where the vessel may be compressed, such as the point where the superficial femoral artery passes through the adductor muscles.

The signs of pallor, coldness, paralysis, and pain do not extend proximally to the level of the embolus. In determining the location of the obstruction, the next major branch proximal to the level of these signs or, when it is possible to palpate a proximal pulse, the major division of the vessel between the level of coldness and pallor and the last palpable pulse will be the most likely location of the embolus. Oscillometric readings will also be of value in determining the site of the obstruction, as the readings will be greatly diminished below the point of arterial occlusion. The location of the embolus is usually not difficult.

Coincident with the impaction of an embolus in an artery, a reflex arterial spasm occurs in the regional vessels distally and to some extent proximally. This results in further decreased blood flow to the area. Shortly thereafter, thrombosis starts in the column of blood in the vessel above and below the obstruction. This is called the propagated clot.

The subsequent course of the circulation in the part distal to the obstruction is dependent primarily upon the degree and persistence of reflex arterial spasm, and the time of onset and extent of intraarterial thrombosis or propagated clot. Pronounced arterial spasm reduces markedly the effectiveness of the collateral circulation and, if persistent, will diminish the chances of success of nonoperative therapy in preserving viability in the involved part. Persistent severe arterial spasm also shortens the time interval during which the performance of an embolectomy may be expected to preserve viability distal to the obstruction.

Extensive thrombosis of the arterial tree distal to the embolus also decreases the effectiveness of both operative and nonoperative forms of therapy in preserving distal tissue viability. If nonoperative therapy is utilized, the life of the part distal to the arterial obstruction is dependent upon the collateral circulation; and for the collateral circulation to provide an adequate blood supply, the arterial system distal to the embolus must remain patent. Embolectomy cannot be successful if a major portion of the distal arteries is thrombosed. The rate and extent of thrombosis in the slowed circulatory flow distal to an embolus varies greatly in individual cases, due partially to unknown influences. Persistent distal arteriospasm causes further slowing of the flow of blood and encourages intravascular thrombosis. In general, the extent of propagated clot is directly related to the interval of time between the onset of the embolus and the institution of therapy (13).

TREATMENT. Prompt recognition and the institution of early therapy are essential for effective results in this condition. The two complications to combat are arteriospasm and intraarterial thrombosis. As soon as the diagnosis is made, systemic heparin and papaverine should be administered and the extremity should be placed in a position slightly below the level of the heart and protected from mechanical or thermal injury. If the occluded vessel is a critical one in the blood supply of the limb, prompt embolectomy should be performed, except in unusual conditions. Rarely, the associated cardiac condition is so critical as to contraindicate the most simple operative procedure under local anesthesia. In such circumstances, in addition to the measures outlined above, the injection of procaine solution to block the sympathetic nerve supply of the involved extremity may be considered. Contrary to some former recommendations, current reports emphasize the desirability of performing embolectomy in cases of upper extremity embolism (10, 12, 14). In the cases of Shumacker and Jacobson, amputation was required in four of six cases of upper extremity embolism not treated by embolectomy. Cerebral or visceral (i.e., splenic, renal, mesenteric) arterial emboli are treated by nonoperative means. Embolectomy of the superior mesenteric artery has been attempted recently in a limited number of cases. The procedure, however, will require further evaluation before its efficacy can be established.

Embolectomy in the extremities is performed with local anesthesia. Exposure of the terminal aorta or iliac vessels requires a general anesthetic. The site of the embolus is exposed. The vessel is isolated proximally

after dependent upon collateral channels. It was, therefore, important to delay definitive treatment for a period of approximately three months, as recommended by Reid (7), to permit adequate collateral circulation to develop. The disadvantages of such a delay were: 1. increased cardiac strain and possible cardiac failure, if the fistula were large; and 2. the development of the desired collateral circulation added greatly to the technical difficulties and hazards of subsequent operation due to the extreme vascularity of the tissues surrounding the fistula. Spontaneous closure of the fistula occurs in only approximately 4 per cent of cases as reported by Seeley (8), and the expectation that such might take place is not a sufficient indication to delay treatment.

Currently available technics of vascular suture, anastomosis, and grafting are sufficiently reliable that there is no reason to delay direct surgical repair unless there are existing contraindications, such as 1. other life-threatening injuries; 2. poor operability from the standpoint of hypovolemia, severe infection, myocardial decompensation; and 3. lack of adequate facilities and trained personnel.

The principles of immediate surgical repair consist of securing control of the artery and vein proximally and distally to the site of injury, evacuation of the hematoma, and direct suture of the laceration or lacerations of the artery. If the arterial wall is badly damaged, excision of the area with end-to-end anastomosis or grafting should be done. The laceration in the vein, if minimal, may also be sutured, provided the vessel is patent, or flow may be re-established by simple removal of a fresh clot; otherwise the vein should be ligated.

ACUTE ARTERIAL OCCLUSION

Nontraumatic acute arterial occlusion may be caused by 1. arterial emboli or 2. arterial thrombosis. In some cases it is difficult to distinguish between the two as causes of acute arterial obstruction. Generally, however, the suddenness with which the onset of symptoms occurs will suggest embolic occlusion. Arterial spasm associated with venous thrombosis may at times be so severe as to suggest the presence of an arterial obstruction.

1. Arterial Emboli. The most frequent site of origin of arterial emboli is within the heart of the patient with rheumatic heart disease (9). Rheumatic heart disease was present in 31 of 55 patients with arterial emboli reviewed by Shumacker and Jacobson (10). Other diseases of the heart associated with the formation of intracardiac thrombi and the site of origin for peripheral emboli in their cases were: arteriosclerotic heart disease, hypertensive cardiovascular disease, myocardial infarction, and toxic goiter with auricular fibrillation. The left atrial appendage is the most frequent site of intracardiac thrombus formation in patients with rheumatic heart disease, mitral stenosis, and auricular fibrillation. Garvin (11) found mural thrombi in 43.3 per cent of 60 patients in whom auricular fibrillation had occurred; 86.5 per cent of the thrombi were located in the atria. In the series of cases reported by Warren and associates (12), 12.5 per cent of the emboli occurred in patients in whom no source of the embolus was clinically evident.

The seriousness of arterial embolization and the cardiac disorders usually associated with this condition is indicated by the patient mortality in a series of 200 patients reported by Warren and associates of 28.4 per cent during a seven-year period and 38.7 per cent in the preceding ten-year period (12). The causes of death in the hospital in 67 of these 200 patients were as follows:

Cause of Death	*Number of Cases*	*Per Cent*
Cerebral embolism	20	30 0
Cardiac failure	19	28 5
Mesenteric embolism	11	16 5
Myocardial infarction	7	10 5
Cerebral and mesenteric embolism	1	1 5
Pulmonary embolism	2	3.0
Other	7	10.5

SYMPTOMS. With an arterial embolus there is a sudden onset of pain, coldness, numbness, and paresis. The pain at times is quite transitory, and numbness and loss of function of the part may be the patient's chief complaints. On examination the extremity distal to the embolus is pale, cyanotic, and cold, and there is anesthesia and loss of motor function. The embolus passes from the heart distally into the arterial system until it encounters a vessel of insufficient luminal diameter to permit



Fig. 3. X-ray of the abdomen. Extreme calcification of aorta and iliac vessels. Areas of calcification visible in upper left abdomen in an aortic aneurysm. While patient was in the hospital he developed severe pain in the upper abdomen with marked tenderness and muscle spasm. Early gangrene of entire small intestine found at operation due to atheromatous obstruction of superior mesenteric artery.

which may or may not be at fault; angiospasm; Raynaud's disease; erythromelalgia; acrocyanosis.

DISEASES DUE TO STRUCTURAL CHANGES IN VESSELS

Great strides have been made in recent years in the surgical treatment of the most common cause of chronic circulatory insufficiency, *arteriosclerosis obliterans,* involving large and medium sized arteries (Fig. 3). The exact cause of this process, and therefore its prevention, is not clearly understood (15, 16). Vascular changes similar histologically to those observed in humans may be produced in experimental animals by the simultaneous oral administration of an antithyroid drug and cholesterol (17, 18, 19) (Fig. 4). This process is typically encountered in the elderly male patient but is seen in both sexes. It may rarely occur in individuals under the age of forty. The presence of diabetes seems to predispose to this condition as it occurs earlier, and almost invariably the condition accompanies advancing age in diabetic patients. Although atheromatous vascular changes are usually generalized they may, particularly in younger patients, be localized, producing complete segmental obstruction of a major artery without evidence of significant disease elsewhere in the vascular system. The arteries of the lower extremity are particularly prone to involvement.



Fig. 4. Microscopic transverse section (low power) of an artery showing changes due to arteriosclerosis. Note that the hypertrophy of the intima partially obliterates the lumen. There is an extensive deposition of fat in the thickened intima, which can be seen better in sections specially stained to show fat (e.g., Sudan stain).

and distally and occluded at these points, while a longitudinal arteriotomy is performed to expose the embolus. After removal of the embolus, if there is not a free flow of blood from both ends of the vessel, the obstructing propagated clot is aspirated, first from the distal arterial tree and then proximal to the arteriotomy. For extensive propagation of the clot distally in the lower extremity, Dye and his associates (14) have cannulated the posterior tibial artery and flushed the thrombus in a retrograde fashion from the distal arterial tree with heparin solution. If an adequate blood flow cannot be obtained from the proximal end of the artery by aspiration, and the wall of the vessel does not indicate extensive atheromatous changes that are probably associated with primary thrombosis rather than embolism, the next higher major division or branching of the vessel should be exposed and treated in similar fashion. Under such circumstances, the level of the embolus has been misdiagnosed, and, although propagated clot may be aspirated from a vessel, an impacted embolus will resist removal by this means. The opening in the vessel is closed with a delicate running over-and-over silk suture. Heparin solution is instilled distally as the vessel is closed. Postoperatively, motion of the extremity is encouraged and systemic heparinization is maintained for a period of seven days. The decision must then be made with regard to placing the patient on prolonged anticoagulant therapy with dicumarol to reduce the risk of subsequent emboli since recurrent emboli are common.

2. **Arterial Thrombosis.** The signs and symptoms of acute arterial thrombosis are similar to those described above and, as stated, may at times be difficult to distinguish from an obstructive embolus. Frequently, however, they are more gradual in onset and there is usually a preceding history suggestive of vascular insufficiency, such as intermittent claudication in the lower extremities.

Thrombosis is associated with arteriosclerotic changes in the vessel wall with intimal thickening and gradual reduction in the caliber of the lumen. The development of collateral circulation is encouraged by this gradual occlusion, so that the final complete obstruction by the thrombus does not cause the severe ischemic symptoms that are associated with the occurrence of an embolus in an otherwise normal vessel. The sclerotic changes are frequently most severe at an arterial bifurcation, but may occur anywhere in a vessel; therefore, the location of the obstruction is made more difficult. This difficulty is increased by the presence of the collateral circulation, which may prevent ischemic changes for variable distances down the extremity.

The character of onset, the presence or absence of cardiac disease which would be compatible with the formation of mural thrombus and emboli, and the evidence of generalized arteriosclerosis are prominent criteria that are of assistance in the differential diagnosis. Gradual thrombotic occlusion is best treated by elective operation. This will be described in a subsequent section. The nonoperative treatment outlined above will be of value during the initial period of mild symptoms. For the acute obstruction with pronounced symptoms, which is usually indicative of a thrombus occurring in a vessel with a fairly adequate lumen, immediate exploration with thromboendarterectomy is indicated. The vessel is exposed at the supposed level of obstruction. Tapes are passed about the vessel above and below this point and a longitudinal incision is made through the wall. The thickened intima and thrombus are carefully dissected from the media and adventitia and the dissection is carried above and below the obstructed area. The distal thickened intima must be carefully sutured circumferentially to the media to prevent it from being further dissected by the arterial stream and folded inward to obstruct the lumen. Heparin solution is placed in the vessel as the incision is closed and the patient is maintained on systemic heparin for seven days.

CHRONIC ARTERIAL INSUFFICIENCY

Under this heading may be considered a group of disorders which interfere with the distribution of blood through peripheral areas. They may be classified as: (1) diseases due to structural changes in vessels: arteriosclerosis; thromboangiitis obliterans (Buerger's disease); and (2) diseases resulting from abnormal functional response of the arteries to various stimuli, including those mediated by the autonomic nervous system



Fig. 5. Aortogram demonstrating segmental obstruction of right common iliac artery. The external iliac and femoral vessels are well filled with the radiopaque solution indicating a patent peripheral system or "run off bed" below the obstruction.

Attempts may be made to re-establish circulation in the major arteries when the obstruction is in the terminal aorta, the iliac vessel, or femoral vessel by 1. thromboendarterectomy; 2. excision of the obstructed segment and replacement with a homograft or plastic prosthesis; and 3. bypass graft.

THROMBOENDARTERECTOMY. The thickened intima and obstructing thrombus are carefully dissected from the media and adventitia through a longitudinal incision in the wall of the vessel. If the segment of obstruction is short, the incision is extended and the core dissected under direct vision (22, 23, 24, 25). For more extended areas of obstruction, such as may be encountered in the femoral vessels, a loop stripper may be utilized to free the core blindly from the center of the vessel as suggested by Cannon and Barker (26, 27) (Fig. 6). At the distal end of the dissection, the intima must be meticulously sutured to the media and adventitia to prevent its infolding and occluding the lumen. The arteriotomy is closed with a delicate continuous suture of silk.

EXCISION OF THE OCCLUDED SEGMENT AND REPLACEMENT BY A GRAFT. This method of treatment has been most useful in the treatment of occlusive disease of the terminal aorta and the iliac vessels (28, 29, 30). After gaining control of the aorta and iliac vessel above and below the site of obstruction, the involved segment is excised and replaced by a graft which is sewn to the cut ends of the vessel with a continuous silk suture.

Although vascular homografts have been most widely utilized, various types of plastic prostheses have been found to provide adequate replacement material and are more readily available (31, 32).

BYPASS GRAFT. When treating obstructed vessels, such as the femoral artery, by grafting, it is preferable to bypass the clogged segment by anastomosing the graft end-to-side to the vessel above and below the obstruction rather than by attempting resection of the oc-

Although chronic arteriosclerotic obstruction of other arteries, for instance the coronary and carotid vessels, are of great clinical significance and efforts have been made (20, 21), some of which are quite preliminary, to improve the circulatory capacity of these vessels by surgical procedures, the major concern today is with the diagnosis and treatment of chronic circulatory insufficiency of the lower extremities.

Symptoms and Signs. The characteristic symptom of chronic arterial insufficiency in the lower extremities is intermittent claudication. This is a severe cramping pain in the muscles of the leg brought on by exercise. The location of the pain varies with the level of arterial obstruction. Pain in the gluteal muscles and hip is associated with terminal aortic obstruction; obstruction of the iliac vessels typically causes pain in thigh muscles; and with femoral artery obstruction the pain is in the muscles of the calf. The circulation is adequate to nourish the muscle at rest but unable to meet its metabolic requirements during exercise. The amount of exercise required to bring on these symptoms is a rough measure of the degree of circulatory insufficiency. Rest relieves the pain, but it reappears again with exercise.

A similar type of pain in the muscle groups during rest and a feeling of coldness in the extremity are indicative of a more severe degree of circulatory insufficiency, and, if the process continues, a more or less constant burning type of pain develops which is thought to be due to ischemia of the nerves. Some relief is afforded the patient by maintaining the extremity in a dependent position, although this position encourages the development of edema and interferes further with capillary circulation. The next stage is the development of skin ulcers about the toes, feet or ankles, an expression of ischemic gangrene usually initiated by mild or insignificant trauma.

Obstruction of the terminal aorta produces a characteristic series of symptoms, *Leriche's syndrome*. There is intermittent claudication in the gluteal and thigh muscles which is usually more severe on one side or the other, but is present bilaterally. Impotence is frequently present.

On examination, absent or greatly diminished pulsations are noted in the major vessels. The skin is cool and has a smooth atrophic appearance; hair growth is sparse. When the veins are emptied by stripping them upwards, they fill slowly. Pallor of the skin of the foot is noted on elevation and rubor in the dependent position. The test of *reactive hyperemia* gives considerable information in regard to the adequacy of circulation. Blood flow to the extremity is restricted either by elevation or by inflating a sphygmomanometric cuff for a period of three minutes. In the normal subject, there is an immediate light red flush which extends over the leg, foot, and toes on return of circulation. This is called reactive hyperemia. A lack of intensity or delay in appearance of the flush indicates a poor capillary circulation in the area.

Additional studies which may give confirmatory and, at times, more exact evidence of circulatory disorders are oscillometric readings, digital plethysmography, skin temperature determinations with thermocouples, and the disappearance rate of subcutaneously injected radioactive sodium solutions. Arteriograms, performed by the injection of a radiopaque solution into the artery proximal to the point of obstruction or performed at the time of operation by injection distal to the suspected point of major arterial obstruction, are of value to demonstrate 1. the exact site and extent of obstruction; and 2. the patency of the smaller distal vessels or "run-off bed" (Fig. 5).

Treatment. An extremity with impaired circulation and impending gangrene must be observed carefully to prevent minor trauma. It is best to maintain the extremity at a level slightly below the level of the heart and at room temperature. Both heat and cold should be avoided. Minor skin abrasions should be kept dry and protected from further trauma. Diabetes, if present, should be rigidly controlled. Autonomic blocking agents are not of value in the treatment of vascular insufficiency resulting from *arteriosclerosis obliterans*. Surgical treatment is directed toward 1. re-establishment of circulation in the major arteries; 2. vasodilation by sympathetic denervation; and 3. carefully considered amputation for gangrene.



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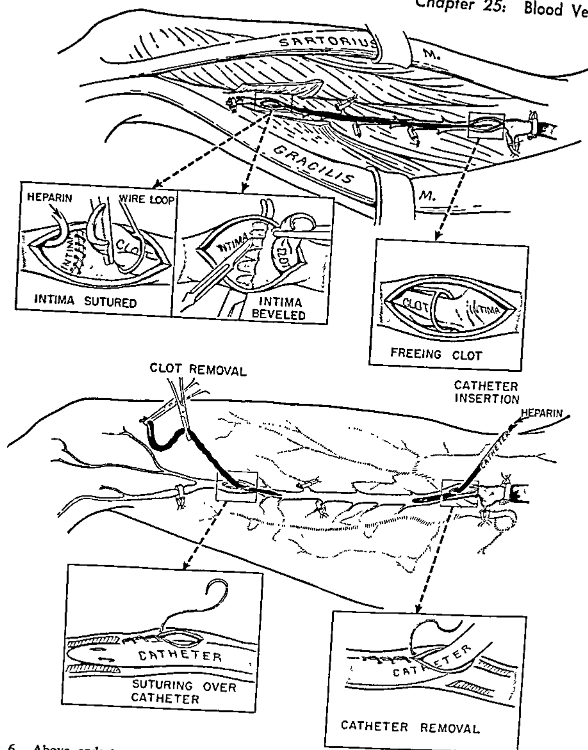


Fig. 6. Above, endarterectomy by semiclosed technic using wire loop stripper. Two arteriotomies are performed. Inserts show management of distal intimal edge either by suturing or beveling. Core removed consists of occluding atheromas plus secondary organized blood clot. Below, repair of vessel after semiclosed endarterectomy over catheter stent. (From Cannon, J. A., and Barker, W. F., Surgery.)

cluded vessel and replacement of it with a graft. Crawford and DeBakey (33) state that,

The most important advantage of this procedure lies in the fact that it not only permits restoration of a normal pulsatile blood flow into the peripheral arterial bed, but also is associated with minimal jeopardy to the existing circulatory and functional capacity of the extremity. The minimal dissection required in its performance reduces the risk of injury and thrombosis to the main artery and to its collateral vessels in the region of occlusion as well as above and below this process.

They were able, by this method, to restore a pulsatile blood flow in the peripheral arterial bed in all but three of 40 extremities so treated. Autogenous vein, arterial homografts, and plastic tubes have all been utilized as bypass vascular substitutes. Although the early results of such procedures have been gratifying, a question has been raised in regard to the continued patency of these grafts. Haye and Warren (34) reported that 70 per cent of their patients suffered closure of the graft after discharge from the hospital. At the present time, it seems difficult to define the procedure of choice for occlusive disease involving the femoral artery. The choice of the authors is thromboendarterectomy. For satisfactory results, however, the procedure must be carefully performed with strict attention to technical details beyond the scope of this chapter. Successful re-establishment of circulation by any of these methods cannot be expected unless the smaller peripheral vessels are patent and there is an adequate "run-off bed."

SYMPATHETIC DENERVATION. Patients with arteriosclerosis obliterans considered unsuitable for a direct attack on the major arterial channels, usually because the disease process is so extensive and because it involves the smaller vessels of the extremity, may, in certain instances, obtain symptomatic improvement by removal or interruption of appropriate portions of the sympathetic nervous system (35, 36). Although the principle effect of sympathetic denervation is vasodilatation of cutaneous vessels, the blood flow through other collateral channels may be increased, and circulation to regional muscles improved. The local anhydrosis produced by sympathectomy prevents maceration of the skin due to excessive sweating, lessens the loss of heat from the extremity, and thereby lowers the circulatory demand.

The degree of elevation of skin temperature over the innervated area, following a block of the sympathetic nerve fibers by the injection of procaine solution into the region of the appropriate sympathetic nerve ganglia, may give an approximate idea of the circulatory improvement to be anticipated from surgical interruption of the nerve fibers. Clinical experience indicates, however, that some degree of improvement may be anticipated in these unfortunate individuals when such tests give evidence of a minimal response. The effectiveness of sympathectomy will depend upon the total number of patent arteries in the extremity and the ability of these vessels to respond by vasodilatation.

The technic of the operation for denervation of the upper extremity (35, 37) involves division of the sympathetic chain between the third and fourth thoracic ganglia, division of the rami to the second and third thoracic ganglia, and division of the second and third thoracic nerves proximal to the sensory root ganglia. The mobilized sympathetic chain is elevated into the wound and sutured to the muscles to prevent nerve regeneration.

The lower extremity is denervated by removal of the second and third lumbar ganglia. This results in complete sympathetic denervation of the foot and lower leg except in its medial aspect. When it is desirable to obtain a maximal increase in circulation from the knee down, the first lumbar ganglion is included in the resection. If bilateral removal of the first lumbar ganglion is considered, it is important to recall that permanent loss of seminal emission has been reported to occur in 54 per cent of patients so treated (35).

AMPUTATION. Any patient with peripheral ulceration or gangrene resulting from inadequate arterial blood flow must be carefully evaluated, not only in regard to the selection of the proper local therapy but also in regard to the management of his general physical condition. The status of the cardiovascular system and the proper regulation of diabetes, if present, are of prime importance.

An effort is made locally to control the extent of gangrene by keeping the affected foot in the position of optimum blood flow, slightly below the level of the heart; the foot is carefully cleansed and kept on a sterile towel, a foot board is used to prevent the bedclothes from rubbing or pressing on the foot and toes, and necrotic material is carefully excised. Sterile saline compresses at body temperature may be alternated cautiously with intervals of exposure to the air to prevent maceration. Penicillin or other antibiotics are indicated, if infection is present. If gangrene is extensive, packing the extremity in ice may markedly reduce the sys-

temic reaction and allow the general condition of the patient to improve.

For minor areas of gangrene in younger patients, amputation of digits may suffice. Healing is rare in elderly patients with arteriosclerosis obliterans following toe amputations. McKittrick, et al. (38) have advocated transmetatarsal amputation in the following conditions: 1. gangrene of all or part of one or more toes, providing that the gangrene and accompanying infection have become stabilized and the gangrene has not involved the dorsal or plantar aspect of the foot; and 2. a stabilized infection or open wound involving the distal portion of the foot, when total excision of the infected area with primary or delayed closure can be accomplished. Success in this type of amputation requires skill in selection of patients and selection of the proper time for operation. The technic of the operation must be meticulous and postoperative care painstaking. These authors report 215 transmetatarsal amputations with two hospital deaths; 33 of the patients failed to heal and required a higher amputation. Satisfactory results were achieved in 135 of the 174 patients followed after discharge from the hospital.

Shumacker and Moore (39) report 61 leg amputations and 53 supracondylar amputations in their series of 121 primary definitive amputations. There was no difference in the mortality between the leg and thigh amputations, although wound complications were encountered slightly more frequently in the leg amputations. They express a preference for the leg, or below the knee, amputation whenever possible. At operation, the extremity is draped so that amputation can be carried out either through the leg or thigh. The gross vascularity noted on trial incision into the leg is used as the principal guide to adequacy of circulation. They feel this method is superior to any method of preoperative evaluation. All eight deaths (6 per cent) in their over-all series were apparently the result of cardiovascular difficulties.

Thromboangiitis Obliterans (Buerger's Disease) (40). This disease is a progressive process involving whole arteries or segments of arteries of medium or small caliber, characterized by thickening of the intima, thrombosis, and periarterial inflammation which may involve the accompanying vein and nerve (Fig. 7). The initial pathologic changes and the etiology are unknown. It occurs most often in young men with the onset of the disease occurring between the ages 25 and 40. Involvement of the lower extremity is much more frequent than the upper. It rarely occurs in the vessels of the viscera. Tobacco smoking is considered a factor in the etiology of the dis-

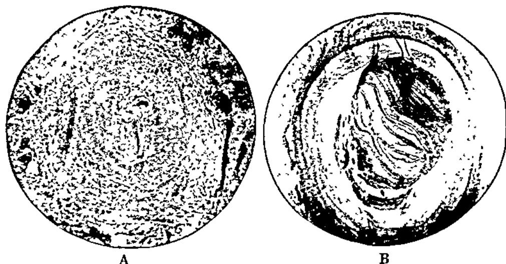


Fig. 7. Photomicrograph of arteries in Buerger's disease; specimens obtained from an amputated leg. A, the entire artery has been obliterated by a thrombus which is fairly well organized. Note the marked inflammatory reaction, with dense fibrous tissue, surrounding the wall of the artery; B, this artery is likewise occluded by a thrombus, but recanalization is taking place. An unusually large amount of proliferation of the intima is present in this specimen.

ease, although rare cases have been reported in nonsmokers.

Clinical Manifestations. The initial symptoms vary. With sudden thrombotic occlusion of the hitherto patent, but narrowed, artery, the onset may be sudden and painful with all the manifestations of an acute circulatory deficiency, *including gangrene (Fig. 8)*. Most often, however, the symptoms, like the pathologic process, develop gradually. In many cases, the first sign will be a peculiar, localized phlebitis of the superficial veins of the leg which subsides after a few days only to recur in some other vein or other area of the same vein. This condition is called *migrating phlebitis* and should lead one to an investigation of the state of the arteries. *Intermittent claudication* may be the first symptom when gradual arterial occlusion occurs. The slowly developing, circulatory deficiency promotes the development of a collateral circulation in the vessels of the skin. As signs of circulatory insufficiency progress, the skin of the foot may become blue or dusky red in color, shiny, and stiff. Changes in the position of the foot will result in marked color changes.

In the later stages slight edema, indolent *ulcers, and eventually gangrene of the toes* may develop. However, gangrene is not extensive; rarely does it involve more than a portion of the toes. The periarterial, inflammatory process which involves the accompanying vein and nerve gives rise to the most characteristic and distressing symptoms. The foot becomes deep red or blue, the pain intense, and the skin hyperesthetic to a degree which will not permit the bedclothes to rest upon it. For some reason, most relief is obtained with the foot hanging over the side of the bed and the hands grasping and encircling



Fig. 8. Buerger's disease. Onset one year ago with tingling and pain in the toes. Pain increased and became very severe. Six months after onset, the lateral three toes became gangrenous at the tip and were amputated. The incision healed, but later broke down, resulting in the ulcer as noted in the photograph. Note the cyanosis of the skin over the distal part of the foot. Pain is still present and now located in the remaining toes and distal part of the foot.

the ankle. Fortunately, the inflammatory process recedes spontaneously in many patients; but in some, when it persists, the patient will beg for amputation. There is almost always a vasospastic element in the circulatory deficiency.

TREATMENT. The most important step in the treatment of Buerger's disease is to prevail upon the patient to stop smoking. The exact etiologic relationship of tobacco smoking to thromboangiitis obliterans is unknown; but there is sufficient clinical evidence to support the view that tobacco smoking exerts a deleterious effect on patients with this disease. Silbert (41) has emphasized that patients who continue to smoke invariably show a progression of the disease despite vigorous treatment, whereas, if they discontinue smoking, the disease tends to remain quiescent, and exacerbations and new vascular occlusions are rare.

During acute exacerbations, bed rest and sedation for pain are indicated. The extremity should be protected from trauma and temperature changes. Every effort should be made to minimize edema by keeping the extremity in a dependent position as little as possible. Drugs to produce vasodilatation may at times be helpful. As soon as they can be tolerated, Buerger's exercises, alternately elevating and lowering the legs to empty and fill the collaterals, are helpful. Sympathectomy is usually indicated to improve collateral circulation after the acute stage has subsided. As the disease tends eventually to be self-limited, and further progression can in most cases be prevented by cessation of tobacco smoking, a conservative attitude should be maintained in regard to amputations, and the procedure reserved for areas of established gangrene. All measures should be utilized to improve the general health of the patient as much as possible.

DISEASES DUE TO VARIOUS STIMULI

Angiospastic Conditions. Spasmodic contraction of the smooth muscle in the wall of an artery or in one segment of a vessel may come about in a number of circumstances as a result of vasoconstrictor impulses reaching the muscle through autonomic nerves. There is frequently a large element of vasospasm in organic disorders such as thromboangiitis obliterans and even arteriosclerosis. Thrombophlebitis, injury of a nonpenetrating type, or rough handling of an artery at operation may also give rise to reflex angiospasm.

The best-known clinical entity of this type is a vasomotor disturbance giving rise to bilateral symmetrical attacks of arterial spasm called *Raynaud's syndrome*. This was described, in 1862, as a disease process which frequently resulted in bilateral symmetrical gangrene (Fig. 9). Occasionally, long-standing cases are seen today in which fibrosis of the arterial wall produces a permanent narrowing of the lumen and atrophic changes in the peripheral part, or even gangrene. The disorder most commonly occurs in women, with its onset in youth or early middle life, and usually affects the hands, only occasionally being encountered in the feet. The first attack is often precipitated by some disturbing emotional experience, and subsequent attacks may be preceded by some psychic upset; however, the history after the initial spasm is generally that cold produces a painful, persistent blanching of both hands with a rather slow return of circulation, sometimes with an abnormal degree of redness, numbness, or paresthesia and pain. Gangrene may develop, but is always superficial and confined to the tips of the fingers. More often, an atrophy of the pulp of the tips of the fingers develops, with a dry, scaly skin. The nails may be distorted. The attacks may be minimized by preventing exposure to extreme cold, wearing warm gloves, or immersing the exposed hands in warm water. When such measures are of no avail, dorsal sympathectomy as described in the preceding section should be considered.

Other types of vasospastic conditions have been said to demonstrate *Raynaud's phenomena* with local signs quite similar to those which characterize Raynaud's disease. Such signs may occur in the hands of workmen who use a pneumatic drill or other vibrating tool; they may also occur in patients with a cervical rib or the scalenus anticus syndrome, with certain nerve lesions, or with poisoning from ergot or such metals as lead. It is important in the examination of the patient with these symptoms to rule out the presence of such etiological factors before concluding that the patient has a true Raynaud's disease.



Fig. 9. Advanced Raynaud's disease. The process is bilateral. Skin of finger is shiny. There is loss of substance in the terminal finger pads and superficial gangrene of multiple finger tips.

Mild vasospastic conditions of the hands and feet are relatively common, particularly in young people. The chief complaints are coldness and hyperhydrosis with occasional attacks of numbness and cyanosis. The symptoms are most severe in cold weather and when the patient is under particular emotional or nervous strain. Treatment entails abstinence from tobacco, avoidance of excessive chilling, attempts to lessen general emotional and nervous strain, and dressing warmly. Systemic autonomic blocking agents are useful. Under severe conditions, sympathetic denervation may be indicated; however, these conditions usually improve as the patient becomes older.

Erythromelalgia (Weir Mitchell's Disease). This disease, as originally described by Mitchell (42), is rare, but its manifestations are dramatic because of its contrast to the manifestations of many other circulatory disturbances. The patient complains of attacks of frequent, constant pain in the feet, particularly when they are held in the dependent position. Examination reveals swelling, redness, and hyperesthesia of the skin, which is usually warm, presumably because of a vasodilation. The disease is perhaps slightly more common among men than women. There is no known satisfactory treatment.

Acrocyanosis. The characteristic feature of this disease is a persistent, bluish-red discoloration of the fingers and hands. Occasionally, the feet are involved; coldness, cyanosis, and excessive sweating are common. The disease occurs most frequently in young women. It is aggravated by exposure to cold. The cyanosis tends to disappear when the extremity is elevated or warmed. Usually, protection from cold is the only treatment indicated. Sympathectomy may be considered in severe cases. *Livedo reticularis* affects both sexes in all age groups. It is characterized by a prominent, reticular, reddish-blue discoloration of the skin of the extremities. *Most frequently, the feet and legs are involved.* Although the discoloration is persistent, it is aggravated by cold. The condition is associated with a narrowing, either organic or spastic, of the local arterioles with dilatation of the capillaries and venules. Ulceration of the skin may occur in affected areas. In the mild case, no treatment is indicated other than protection from cold. More severe

cases, particularly if ulceration is present, may be treated by sympathectomy. Satisfactory results from operation may usually be anticipated.

Arterial Aneurysms. Rupture of *aneurysms of the cerebral vessels* is one of the common causes of subarachnoid hemorrhage. Improved methods of diagnosis by cerebral angiography and treatment by direct surgical attack with closure of the neck of the sac or involved vessel have been developed in recent years. The majority of these aneurysms are thought to be congenital in origin, although they do not produce symptoms until adult life. Mycotic and arteriosclerotic aneurysms of the vessels also occur.

Peripheral arterial aneurysms may be classified as 1. true aneurysms and 2. false aneurysms. False aneurysms have been discussed in a preceding section; they usually result from direct trauma to an artery. Infection and necrosis of the vessel wall from an infected embolus or infection in the vasovasorum may cause rupture of the vessel and the formation of a false aneurysm. A vascular lesion produced in this manner is called a *mycotic aneurysm*. A similar process may occur from an abscess outside the vessel which causes necrosis and disruption of the arterial wall. The aneurysmal sac in these conditions is formed from fibrous tissue which develops about the hematoma surrounding the point of rupture.

The aneurysmal sac of the *true aneurysm* is formed by tissue of the vessel wall itself which has become dilated and expanded. Aneurysms may be called *fusiform* or *saccular* depending upon their shape and their relation to the vessel from which they originate. An aneurysm is considered fusiform when the entire circumference is weakened, thereby allowing a more or less symmetrical dilatation. A saccular aneurysm projects from the artery as a globular mass because of a localized weakness in the vessel wall at one point.

One of the most common aneurysms seen today is a fusiform aneurysm arising in an arteriosclerotic area of the distal aorta. This condition is discussed in Chapter 38. Local pain, swelling, or pulsation may be the first symptoms of an aneurysm; the mass may increase in size slowly or rapidly. Pain at the



Fig. 10. Syphilitic aneurysm of the left popliteal artery. The patient is a Negro, aged 40, who contracted syphilis at the age of 17. The mass, accompanied by pain in the thigh and popliteal region, was noted only during the past six months.

site of the aneurysm or along the course of an adjacent nerve is experienced because of pressure of the mass. The pain is more severe if bone is being eroded. The involved extremity may become cold and pale and, on rare occasions, gangrene may develop. Rupture of the vascular mass with serious or fatal hemorrhage may occur (Fig. 10).

One of the most diagnostic features of aneurysm is the presence of expansile pulsation as detected by careful palpation or by fluoroscopy. This must not be confused with transmitted pulsation, which is noted frequently when solid tumors lie against large arteries.

Treatment. Occasionally, spontaneous cure may occur in saccular aneurysms by thrombosis. This occurred in eight of 119 cases reported by Shumacker (43). Fusiform aneurysms (of such arteries such as the femoral or popliteal), when of sufficient size to produce symptoms, or when there is evidence of rapid enlargement, may be treated by excision and grafting, usually with an autogenous vein graft. In cases of saccular aneurysm, the defect in the wall of the parent vessel may be closed by direct suture. In smaller vessels, such as the anterior tibial or radial,

the vessel may be ligated proximally and distally, and the lesion excised.

VENOUS SYSTEM

Diseases of the veins occur as the result of one or a combination of three basic derangements: valvular incompetency, venous thrombosis, and/or venous insufficiency. Venous disease in the lower extremities is one of the most common ailments suffered by man, and its treatment frequently is inadequate or even detrimentally unsatisfactory because of a failure on the part of the physician to understand the nature of the disease and the mechanisms whereby symptoms are produced.

Anatomy and Physiology. It is important first to understand the basic anatomy and physiology of the venous system of the lower extremities. Of the blood reaching the lower extremities, 85 to 90 per cent is returned to the heart via the deep venous system. The popliteal vein receives tributaries from the deep veins of the leg, becomes the superficial femoral vein in the thigh, and is joined by the deep femoral or profunda femoris vein which drains the muscles of the thigh to become the common femoral vein at the groin. All these veins are normally supplied with valves which, working in conjunction with the constrictive action of the muscles in the lower extremity in ambulation; force the venous blood up the extremity toward the heart. Heart action, per se, contributes nothing to the *mechanism of venous return of blood* from the extremity.

The superficial venous system of the lower extremity, the saphenous system, drains blood from the skin and subcutaneous tissue. It is comprised of the long saphenous system, which drains the superficial tissues of the medial and posterior aspect of the leg and thigh and empties into the common femoral vein at the groin, and the short saphenous system, which drains the superficial tissues of the lateral aspect of the leg and drains into the popliteal vein in the upper portion of the popliteal space. Both systems are normally supplied with valves, and valved, communicating veins join the superficial and deep systems of veins in the lower extremity, normally permitting blood to pass in one direction from superficial to deep system. It should be remembered that, as long as the deep system of veins in the lower extremity is relatively sufficient in its state of patency, the main trunks of the superficial system can be obliterated without evidence that any significant venous insufficiency, superficial or deep, is thereby imposed.

Varicose Veins. The most common venous disease of the lower extremities is varicose veins, manifested by both dilatation and elongation of the veins of the saphenous system (Fig. 11). It is of importance to remember that superficial varicose veins may be primary, i.e., exist in the presence of a normal deep venous circulation, or secondary to deep venous disease. Distinction between primary and secondary varicose veins is sometimes difficult but is of importance in determining proper treatment of the disease. Nevertheless, both primary and secondary varicose veins occur as the result of valvular incompetency in the affected veins.

VALVULAR INCOMPETENCY. The valves in the peripheral veins are extremely delicate,



Fig. 11. Tortuous varicose veins of the legs. Marked varicosities involving tributaries of greater saphenous system bilaterally.

cases, particularly if ulceration is present, may be treated by sympathectomy. Satisfactory results from operation may usually be anticipated.

Arterial Aneurysms. Rupture of *aneurysms of the cerebral vessels* is one of the common causes of subarachnoid hemorrhage. Improved methods of diagnosis by cerebral angiography and treatment by direct surgical attack with closure of the neck of the sac or involved vessel have been developed in recent years. The majority of these aneurysms are thought to be congenital in origin, although they do not produce symptoms until adult life. Mycotic and arteriosclerotic aneurysms of the vessels also occur.

Peripheral arterial aneurysms may be classified as 1. true aneurysms and 2. false aneurysms. False aneurysms have been discussed in a preceding section; they usually result from direct trauma to an artery. Infection and necrosis of the vessel wall from an infected embolus or infection in the vasovasorum may cause rupture of the vessel and the formation of a false aneurysm. A vascular lesion produced in this manner is called a *mycotic aneurysm.* A similar process may occur from an abscess outside the vessel which causes necrosis and disruption of the arterial wall. The aneurysmal sac in these conditions is formed from fibrous tissue which develops about the hematoma surrounding the point of rupture.

The aneurysmal sac of the *true aneurysm* is formed by tissue of the vessel wall itself which has become dilated and expanded. Aneurysms may be called *fusiform* or *saccular* depending upon their shape and their relation to the vessel from which they originate. An aneurysm is considered fusiform when the entire circumference is weakened, thereby allowing a more or less symmetrical dilatation. A saccular aneurysm projects from the artery as a globular mass because of a localized weakness in the vessel wall at one point.

One of the most common aneurysms seen today is a fusiform aneurysm arising in an arteriosclerotic area of the distal aorta. This condition is discussed in Chapter 38. Local pain, swelling, or pulsation may be the first symptoms of an aneurysm; the mass may increase in size slowly or rapidly. Pain at the site of the aneurysm or along the course of an adjacent nerve is experienced because of pressure of the mass. The pain is more severe if bone is being eroded. The involved extremity may become cold and pale and, on rare occasions, gangrene may develop. Rupture of the vascular mass with serious or fatal hemorrhage may occur (Fig. 10).



Fig. 10. Syphilitic aneurysm of the left popliteal artery. The patient is a Negro, aged 40, who contracted syphilis at the age of 17. The mass, accompanied by pain in the thigh and popliteal region, was noted only during the past six months.

One of the most diagnostic features of aneurysm is the presence of expansile pulsation as detected by careful palpation or by fluoroscopy. This must not be confused with transmitted pulsation, which is noted frequently when solid tumors lie against large arteries.

TREATMENT. Occasionally, spontaneous cure may occur in saccular aneurysms by thrombosis. This occurred in eight of 119 cases reported by Shumacker (43). Fusiform aneurysms (of such arteries such as the femoral or popliteal), when of sufficient size to produce symptoms, or when there is evidence of rapid enlargement, may be treated by excision and grafting, usually with an autogenous vein graft. In cases of saccular aneurysm, the defect in the wall of the parent vessel may be closed by direct suture. In smaller vessels, such as the anterior tibial or radial,

the deep venous system is uninvolved and remains satisfactorily functional even when the main trunks of the saphenous systems are removed.

SYMPTOMS. The symptoms of primary, uncomplicated varicose veins are usually minimal. The patient complains at first only of their appearance. Such a complaint in the female patient may be very significant and may demand careful, considered, therapeutic effort. As the condition progresses, the patient may note a heaviness in the legs especially along the course of the varicosities, sometimes a burning of the skin over the veins, a vague aching and tired feeling in the legs, occasionally some puffiness in the feet or ankles, and, at times, premenstrual soreness in the involved veins. Neglected varicose veins may give rise occasionally to a small localized rupture through the skin and frightening but rarely serious hemorrhage, thrombosis and thrombophlebitis of a varicosed vein segment, and, as a very late manifestation, stasis dermatitis and/or stasis ulceration on the skin of the leg in the region of the medial malleolus and on the skin of the lower medial aspect of the leg above the malleolus.

Probably because varicose veins are obvious at a glance, it is common for both the patient and physician to ascribe various symptoms, arising from some unrelated condition, to the varicosities. A word as to some of the symptoms which varicose veins *do not* produce is consequently indicated and has been well summarized by Dr. Geza de Takats (44):

> Greatest caution must be exerted, however, in interpreting a variety of symptoms as being connected with the presence of varicosities. From flatfoot to arthritis of the small joints and ankles, from muscle hernias to arthritis or internal derangement of the knee joint, from chronic inguinal lymphadenitis to arthritis of the spine, slipped disc and spondylolisthesis, from saphenous neuritis caused by a thrombophlebitis exudate in the femoral sheath to an alcoholic polyneuritis, a multitude of conditions should be thought of and excluded before one can attribute the patient's complaints to obvious varicosities.
>
> Varicose veins unless they are visibly inflamed do not hurt day and night; they do not cause cramping on walking unless arterial insufficiency supervenes. They do not produce sciatic type of pain on raising the leg; they do not manifest themselves by shooting radiation along the lateral cutaneous nerve and they do not cause absence of ankle jerks in diabetics. All this is stressed to indicate the necessity of a thorough examination and a proper interpretation of the patient's symptoms. The number of patients with vein ligations and stripping procedures whose symptoms continue or are aggravated by insufficient indication for surgery is considerable.

The major sign of primary varicose veins is essentially the presence on inspection of tortuous, dilated cords of veins occurring along the course of the involved system. The long saphenous system is usually involved alone. Involvement of the short saphenous system alone is rarely seen; it rather tends to occur as an added factor in more severe involvement of the long system. In long-standing varicosities, there may be brownish pigmentation over the malleolar and lower medial aspects of the legs.

DIAGNOSTIC AIDS. In the past, much attention has been given to various tests to determine the functional status and source of filling of varicose veins. Thus, in the *Trendelenburg test* (Fig. 13), the veins are emptied by elevating the extremity, applying a rubber tourniquet high on the thigh, and observing the degree of filling which occurs when the patient stands. If no filling or very slow filling results, the perforating veins between the superficial and deep systems can be considered competent. If the varices fill with the tourniquet in place, the perforating veins are incompetent and, if engorgement occurs, the deep system is probably insufficient. Competency of the perforating veins can also be tested by the *Perthes test*. The tourniquet is applied with the veins full and the patient standing. The patient raises up on his toes several times, and the varicosities are then observed for emptying, which should occur in the presence of competent, perforating veins to the deep system.

From a practical viewpoint, these tests are of most importance in aiding a critical evaluation of the status of the deep venous system. An array of elaborate tests involving radioactive solutions, x-ray venograms, and manometric determinations are available. Such tests are expensive, sometimes misleading,

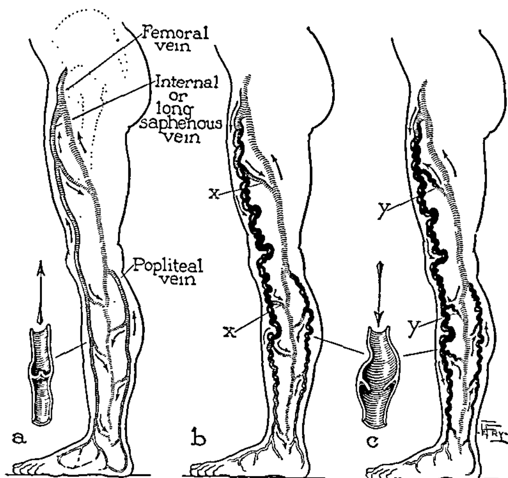


Fig. 12. a, diagrammatic drawing showing the relative relationship of the deep to the superficial veins of the lower extremities. As shown by the arrows, the direction of blood flow in the superficial and deep veins is upward, whereas the direction of blood flow in the communicating veins is from the superficial to the deep veins. This is possible because of competent valves in the deep, superficial and communicating veins. b, diagrammatic drawing showing varicosities of the superficial veins with incompetency of the valves in these veins. There is a reversal of blood flow in the superficial veins, i.e., from above downward. Because, however, the valves in the communicating veins (X) are still competent, the direction of blood flow is normal, i.e., from the superficial to the deep veins. c, diagrammatic drawing showing varicosities of the superficial and communicating veins with reversal of blood flow in both sets of veins. Because of incompetency of the valves in the communicating veins, as shown in Y, the direction of the blood flow is from the deep to the superficial veins instead of from the superficial to the deep as normally occurs. (From Ochsner. Lewis-Walters, Practice of Surgery, W. F. Prior.)

thin, fragile, precision-fitted, bicuspid structures. Once adult growth is reached, there is no evidence that these valves are capable of further growth. Any condition which leads to an increase in venous diameter in the region of a valve will result in leakage in the valve so that a vicious circle is set up and the condition becomes progressive. When a given valve becomes incompetent, increased pressure is placed on the next valve below so that its competency is jeopardized. The result is progressive dilatation of the entire venous system, thus producing *varicose veins* (Fig. 12). Only the long and short saphenous systems are significantly involved in this disease. Undoubtedly the most common etiologic factor is repeated pregnancy; in the last trimester, venous hypertension and dilatation in the extremities is apt to develop because of the intrapelvic growth of the fetus. Occupations which require prolonged standing and walking also foster development of this condition. There is some indication that persons of the thin, aesthetic, "loose-tissued" build are also more prone to develop varicosities than others. It is, under the circumstances, enumerated above that *primary varicose veins* are produced. In this instance,

such secondary varicosities may be indicated for various reasons, but it should be undertaken only with the full realization that further venous insufficiency and, hence, enhanced leg swelling may be imposed.

TREATMENT. The preferred treatment for saphenous varicose veins consists basically of vein ligation and stripping. Subsequent injection of sclerosing agents into residual, varicosed tributaries or even their secondary surgical interruption may be necessary. The use of the procedures of high saphenous ligation alone, ligation plus distal injection of sclerosing agents, or multiple ligations has not shown a satisfactory incidence of long-term improvement. On the other hand, the application of long saphenous vein ligation and stripping to the average case of long saphenous varicosities can be expected to result in a highly satisfactory, relatively permanent improvement both in symptoms and appearance.

The object of vein ligation and stripping is not only to interrupt the saphenous vein at the junction with the common femoral vein but also to remove the entire saphenous trunk from groin to ankle, thereby disconnecting not only the major tributaries from a source of engorgement but also obliterating the communicating veins between the superficial and deep systems. This latter objective is accomplished by removal of the trunk, since the bulk of the communicating veins issue from the main saphenous trunk. The operation can be performed quickly and with great facility by using a Zollinger-type (45) vein stripper. This instrument consists of a long flexible cable with a threaded end to which tips of various sizes may be attached.

At operation, the distal end of the long saphenous vein is exposed at its constant position anterior to and just above the medial malleolus. The vein is isolated and divided. The distal end is ligated, and the stripping cable with the thinnest tip attached is inserted into the proximal end of the vein and threaded up the entire length of the extremity to where the tip can be palpated in the saphenous vein at the saphenofemoral junction just below the groin crease. The saphenous vein is then exposed at this level and divided. The proximal end is traced to the saphenofemoral junction, dividing and ligating all tributaries which are encountered. The tip of the stripping cable is then delivered through the distal end of the saphenous vein at the thigh. The thin tip is exchanged for a large one and the vein is securely ligated about the stripping cable. A traction handle is then attached to the other end of the cable at the ankle, and the cable is withdrawn. The saphenous trunk telescopes on the cable, and all communicating and tributary veins are disconnected by tearing them from the main trunk as it is removed. During the procedure, the extremity is maintained in an elevated position and pressure is applied along the stripping tract until clotting in the torn tributory veins has occurred. Pressure bandages are applied, and the patient is ambulated beginning with the day of operation.

Secondary ligations and occasional injections may be necessary, but frequently complete relief is obtained by the single procedure. If the short saphenous system is involved, it can be similarly treated by removal of the short saphenous trunk from the external malleolus to the saphenopopliteal junction.

Venous Thrombosis. The occurrence of spontaneous clotting of blood in the veins of the lower extremity is much more common than is generally realized. Thrombosis is most apt to occur in the deep system of veins but can be encountered in the superficial system as well. The pathological manifestations which ensue produce signs and symptoms which are often confusing and are frequently misinterpreted. The factors which lead to deep venous thrombosis are not always apparent. However, any situation which results in relative stasis of blood flow in the deep veins of the legs, a change in the intimal lining of the vein, or an alteration in the clotting mechanism of the blood can also result in deep venous thrombosis. Consequently, the condition is commonly seen in trauma, especially that which involves fractures of the lower extremities, cardiac disease, the postoperative or postpartum period, certain blood dyscrasias, and possibly in patients suffering from certain carcinomas.

SYMPTOMS. Once thrombosis occurs in the deep venous system, a highly variable array of signs and symptoms may ensue. If the

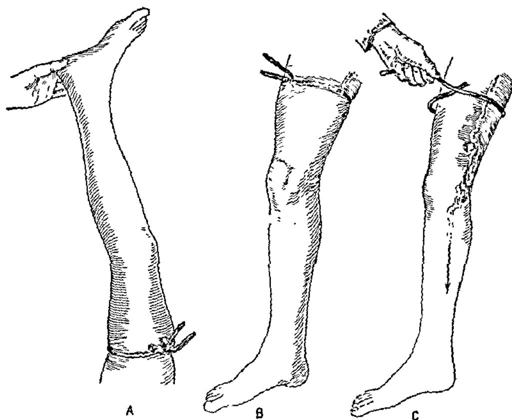


Fig. 13. Principles in the performance of the Trendelenburg test. A, with the patient lying supine and the extremity elevated, the blood is forced out of the veins by stroking the leg from above downward; a tourniquet is then applied, but only tight enough to constrict the superficial veins and not the femoral. It is easier to determine the correct amount of pressure by holding the ends of the tourniquet in the hands. B, negative *constriction test:* the patient was asked to stand and the rapidity of filling of the saphenous system noted. In this case these veins did not fill during thirty seconds observation: the test is therefore negative. C, positive *release test;* the tourniquet is released and the fall of the blood column in the saphenous vein observed. In this case the column fell immediately; the test is therefore positive. If the saphenous system is already filled before the tourniquet is released, it must be emptied by again placing the patient on the table. For interpretation of results see text.

and not without an incidence of morbidity. Rarely do they yield more information than can be obtained from a properly elicited history and carefully performed physical examination.

As will be indicated in more detail below, disease of the deep venous system usually begins as the result of deep venous thrombosis. Although subsequently the patient may become asymptomatic, there will usually be an elicitable history of an episode of pain and swelling in one or both lower extremities. The swelling in the extremity may persist as a chronic complaint. Over the course of time, superficial varicose veins are apt to develop in an attempt on the part of the system to improve venous return from the extremity by collateral circulation. For the most part, increased flow in collateral veins can only be obtained by dilatation of the vein, which promptly results in valvular incompetency and progressive varicose veins. Such a patient may well seek treatment because of the varicose veins or more often he will seek surgical treatment for chronic edema of the lower extremities. Both the patient and the referring doctor will often believe the latter to be the result of varicose veins rather than of a long-past episode of deep venous thrombosis which had resulted in deep venous insufficiency from which, in turn, was produced both the chronic leg edema and the secondary saphenous varicose veins. A diagnosis of *secondary varicose veins* can be strongly suspected on the basis of a history suggestive of a previous episode of deep venous thrombosis and a presenting complaint of leg swelling plus varicosities. Surgical treatment of

mechanism whereby blood clots. Furthermore, heparin is almost instantly effective. In addition, an antidote, protamine sulfate, is available which neutralizes the effect of heparin in minutes. In venous thrombosis, when heparin therapy is begun promptly in adequate dosage and over a sufficient length of time, the therapeutic result is usually quite dramatic, effective, and adequate. Because heparin is expensive and must be administered parenterally, there has been a tendency to use it in small amounts and for short periods of time and to rely basically on the cumarin drugs, such as dicumerol (47), to produce an anticoagulative effect. Unfortunately, the cumarin drugs act at only one point in the clotting reaction; namely, they depress prothrombin production by the liver. Consequently, the action is anticoagulative only to a limited degree and is reliably effective only if the prothrombin level is suppressed below 30 per cent of normal. A prothrombin level below 10 to 15 per cent of normal is dangerous.

Neutralization of the curmarin effect is a time-consuming process. Hence, use of the cumarin drugs in the treatment of venous thrombosis is unreliable, dangerous, and basically effective only to a limited degree. On the other hand, these drugs, when used in the prophylaxis of venous thrombosis have a definite place and value.

With the advent of anticoagulants, surgical therapy of acute deep venous thrombosis has been neglected. Nevertheless, it has an undeniable place in the treatment of this condition (48, 49). If a sublethal pulmonary embolus has occurred in a patient with venous thrombosis, the only reliable protection from further, possibly lethal, emboli is surgical interruption of the vein which is the source of the embolism at a level above the site of the primary venous thrombosis. This closes the route whereby the offending clot can reach the pulmonary circulation. The use of heparin still remains the basic therapy for this condition, but it should be remembered that venous interruption may be combined with heparin therapy with only a momentary, incomplete interruption in the latter while surgery is performed. Furthermore, it is to be remembered that there is no evidence that interruption of a vein involved with venous thrombosis will significantly affect the status of venous sufficiency or valvular competency later manifested by the venous tree involved. There is, indeed, some indication that vein interruption has a beneficial effect on the subsequent subsidence of acute deep venous thrombosis.

Postphlebitic Complications. Once the acute manifestations of deep venous thrombosis have subsided, the venous circulatory status of the afflicted extremity gradually enters a chronic state which, within a few weeks, may leave no detectable residual or may show certain permanent chronic manifestations of a very serious nature. Such an extremity is known as a postphlebitic extremity. The disease which such an extremity will manifest depends on several factors. On the one hand, if an episode of deep venous thrombosis is detected early, when involvement is limited to the veins of the calf, and the disease is treated vigorously and adequately with heparin, even the long-term residual manifestations, in the absence of further episodes of thrombosis, may be minimal or lacking. On the other hand, an extremity in which clotting in the entire deep venous system has occurred is apt to handicap the patient for the remainder of his life.

The reparative processes which occur are remarkable, but frequently inadequate. Veins in which thrombosis has occurred tend to recannalize. Nevertheless, their valves are permanently destroyed and the total effective drainage which can be restored through such a vein by recannalization is very limited. There is a remarkable tendency for collateral venous drainage to develop, but this too is limited; and, since circulation through collateral veins can be increased only by the occurrence of dilatation of these veins, their valves are automatically made incompetent. Consequently, such an involved extremity enters into a permanent condition of venous valvular incompetency and venous insufficiency. Neither of these conditions will result in very significant symptoms as long as the involved extremity is maintained at the same hydrostatic level as the heart; i.e., as long as the patient remains in a horizontal position, his extremity will manifest no significant detectable signs or symptoms. However, once the upright position is assumed, the

formation of the clot is slow and does not irritate the wall of the vein, a condition referred to as *phlebothrombosis* occurs. In this situation, the clot is soft, loosely adherent to the vein wall, and prone to break loose and travel into the lungs, resulting in *pulmonary embolism* and *pulmonary infarction*. Thus, the first inkling of deep venous thrombosis that the patient may manifest is sudden death from massive pulmonary embolism. More commonly, the patient may complain of chest pain which is relatively sudden in onset and usually severe. Hemoptysis may then occur. Chest x-rays taken 24 hours or more after an embolus has lodged in the lung may show findings consistent with a diagnosis of pulmonary infarction. Repeated pulmonary infarctions may occur in the complete abscence of detectable signs or symptoms in the involved extremity. The earliest detectable manifestation of so-called *bland phlebothrombosis* in the extremity may be a slight swelling of the foot and ankle, a relative dilatation of the superficial veins of the foot and ankle, a relative warmth of the foot and leg, mild cyanosis, minimal calf muscle tenderness, or a combination of some or all of these signs. The patient may have no complaints or may note muscle soreness in the calf on ambulation.

It should be remembered that signs and symptoms in the extremity occur in direct relation to the amount of reaction to the clot which occurs in the wall of the vein and perivenous tissues. In the instance discussed above, where the reaction to the clot is minimal, signs and symptoms may be absent or minimal, but the risk of pulmonary embolus is very great. This condition has been designated as bland phlebothrombosis. The local reaction to the venous clot is bland, but the distant lethal potential is very much the opposite.

In other instances, the thrombosis in the entire deep venous system seems to occur with great rapidity. The clot suddenly occludes the entire main deep venous trunk. The clot is firm and sticky. It tends to adhere and, at the same time, irritate the vein wall. The result is a combination of the effects of sudden, massive, deep venous occlusion and a massive, sterile inflammatory reaction in the entire deep venous system. It is this type of reaction which is recognized as *thrombophlebitis*. The extreme of this situation is known as *phlegmesia alba dolens*, the classical example of which is the so-called milk-leg of pregnancy. In this condition, the onset is relatively sudden. The involved extremity from toes to groin becomes swollen, painful, cold, and blanched. In these cases, pulmonary emboli are rare, since the clot is tightly adherent to the vein wall. Early in the course of the disease, the inflammatory irritation results in vasospasm which involves the arterial tree. Hence, the extremity is cold and pale. Frequently, no popliteal or pedal pulses are initially palpable. As the disease progresses, the sterile inflammatory reaction becomes more manifest: the extremity becomes warm and erythematous, dilatation in the superficial veins appears, and the patient runs a febrile course. For this inflammatory reaction, it is a common practice to administer antibiotics. Since no infectious agent, especially no bacterial infectious agent can be demonstrated, the use of antibiotics has no value whatsoever and, indeed, is contraindicated.

In the past, the two extremes in the manifestations of venous thrombosis mentioned above, i.e., bland phlebothrombosis and thrombophlebitis, have been designated as separate entities. Actually, depending upon the extent of the clotting phenomenon and the amount of sterile inflammatory reaction incited thereto, this condition may manifest itself in any possible combination of the two extremes.

Indeed, in a given case, bland phlebothrombosis may be seen to progress on an acute or chronic basis to a fulminating thrombophlebitis. Furthermore, an acute thrombophlebitis may gradually subside down the scale of local severity to a bland phlebothrombosis and somewhere along the course may discharge one or more pulmonary emboli.

TREATMENT. The basis of treatment for deep venous thrombosis in any form consists of administration of an anticoagulant. The only truly effective anticoagulant available is *heparin* (46). By its action, heparin is effective in blocking the blood clotting mechanism at every one of the numerous reactions which are involved in the complex chemical

ulcer. Here, excision and grafting or simply grafting the ulcer may occasionally be indicated to hasten healing. Frequently there are numerous varicosed veins which seem to "feed" the ulcer. Radical elimination of all superficial veins in the area proximal to the ulcerated area, after healing has first been obtained, will be helpful in the later management of the extremity in avoiding recurrent ulceration (50). The place of ligation of any segment of the deep venous system to eliminate the effects of valvular incompetency is highly dubious, even though recommended by some. Frequently the vein in question is already a fibrosed cord. If the vein to be ligated is patent then, at the very best, by ligation one is trading some theoretical prevention of the effects of valvular incompetency for a superimposed degree of increased venous insufficiency. So far, no satisfactory or reliable surgical method of correcting deep venous insufficiency and valvular incompetency has been devised. Consequently, all efforts at the treatment of the postphlebitic extremity are palliative at best. It is important that these efforts follow rational physiological principles.

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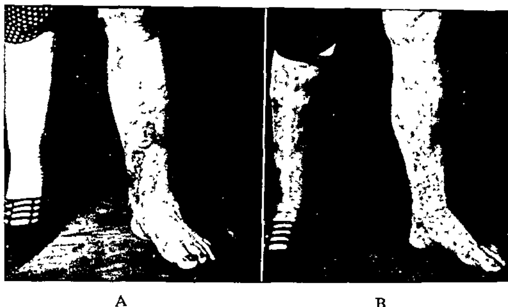


Fig. 14. Varicose ulcers of the leg. A, ulcers due to varicosity are usually single, not multiple. B, appearance of leg several months later, after obliteration of the veins by injection of a sclerosing agent. Note that the ulcer has healed and that the varicosities are obliterated. (Washington University Clinic.)

effect of gravity becomes apparent. Untreated, the extremity will manifest chronic edema, at least from toes to knee, and frequently of the thigh as well. Dilated secondary varicose veins will gradually appear, and over the course of time a brown pigmentation in and around the lower leg will be seen which is usually most marked on the medial aspect of the lower third of the leg, including the malleolus. The pigmentation is frequently circumferential in the region. The skin becomes thickened and edematous. It may undergo episodes of inflammation known as *stasis dermatitis,* and finally indolent ulceration of the skin in the region occurs. Such ulceration is referred to as *stasis* or *stasic ulceration* (Fig. 14). As long as the patient spends any significant time on his feet each day, such ulcerations will not heal and will tend to enlarge. They will be refractive to *any* treatment which permits continued daily ambulation. The imposition of bed rest, elevation of the extremity and the simplest of local cleansing measures will invariably result in slow, but definite healing of such an ulcer by secondary intention. Nevertheless, as soon as the patient again assumes the upright posture the swelling and ulceration will recur.

Prevention of this recurrent ulceration and swelling in the postphlebitic extremity is extremely difficult and usually possible only if certain handicaps are imposed upon the patient. Numerous operations and therapeutic regimens have been reported, but none are really satisfactorily effective. The best that can be offered such a patient is a plan of palliative management which consists of three main modalities: 1. application of external elastic support; 2. counteracting the effects of gravity; and 3. extirpation and ligation of superficial veins in the region of the skin area which is ulcerating.

Using external elastic support means wearing properly fitted elastic stockings whenever the patient is ambulatory. Counteracting the effects of gravity means that the patient must interrupt his activities during the day for at least three or four 15- to 20-minute periods; during this time he should lie down with the extremity elevated higher than the level of the heart. In addition, the foot of his bed should be elevated four to six inches. Furthermore, it may be necessary for the patient to change his work so that prolonged standing and walking can be avoided.

Numerous operations have been described for the management of this syndrome but it should be realized at the outset that there is no known operation that will alleviate postphlebitic leg edema. Surgery is of occasional value only in the management of chronic leg

ulcer. Here, excision and grafting or simply grafting the ulcer may occasionally be indicated *to hasten healing. Frequently there are* numerous varicosed veins which seem to "feed" the ulcer. Radical elimination of all superficial veins in the area proximal to the ulcerated area, after healing has first been obtained, will be helpful in the later management of the extremity in avoiding recurrent ulceration (50). The place of ligation of any segment of the deep venous system to eliminate the effects of valvular incompetency is highly dubious, even though recommended by some. Frequently the vein in question is already a fibrosed cord. If the vein to be ligated is patent then, at the very best, by ligation one is trading some theoretical prevention of the effects of valvular incompetency for a superimposed degree of increased venous insufficiency. So far, no satisfactory or reliable surgical method of correcting deep venous insufficiency and valvular incompetency has been devised. Consequently, all efforts at the treatment of the postphlebitic extremity are palliative at best. It is important that these efforts follow rational physiological principles.

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26

THE LYMPHATIC SYSTEM

The tissue spaces between capillaries and cells are bathed by a fluid or lymph which is continuously collected by the lymphatic system and delivered into the veins of the neck. This system consists of channels called the lymphatics, which pass through a series of tiny lymph nodes located at various parts of the body (Fig. 1). The lymphatic system may be called part of the circulation inasmuch as much of the lymph originates from the blood stream as a cell-free filtrate across the capillary walls. However, the lymph also contains elements resulting from cellular activity and tissue metabolism. Analysis of normal lymph reveals one important difference from blood plasma, it contains much less protein, usually less than 1 per cent except when draining from areas of inflammation where the value may approach that of plasma. Nevertheless, it normally often contains enough fibrinogen to coagulate, although it does so much more slowly than blood. Its composition differs from the area of the body drained. For example, chyle is a milky mixture of emulsified fat and lymph which is found in the lymphatics draining the small intestines. Small lacteals in the villi of the intestine collect the emulsified fats from the intestines and conduct them to larger trunks in the mesentery. During starvation, however, this fluid will obviously contain but little fat. Chyle is of surgical importance as it escapes during injury from the thoracic duct or its tributaries into the peritoneal or pleural cavity.

Although lymph channels were described three centuries ago, our present knowledge has followed the investigations carried out during recent decades, particularly those of Florence Sabin (1) and Drinker (2). Lymphatic channels drain all tissues in the body except the brain, forming a number of re-

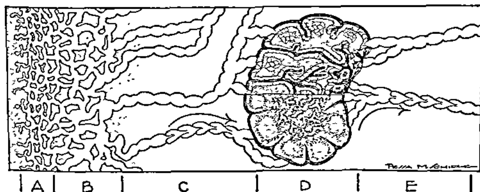


Fig. 1. The structural basis of the lymphatic system (semidiagrammatic). A, the irregular, blindly ending lymph capillaries. B, the reticular network. C, the afferent tubular lymphatics containing valves. D, the lymph node, presenting (above) the lymph sinuses and (below) the histologic picture. E, the efferent lymph vessels, showing above the arrow numerous valves. (From Curtis. Christopher, Textbook of Surgery, W. B. Saunders.)

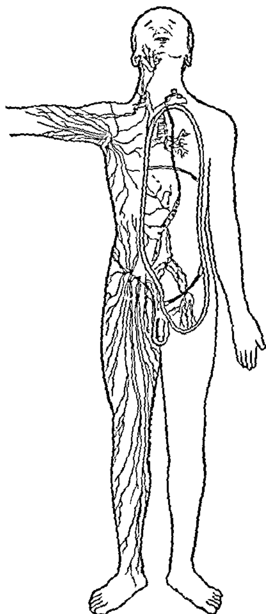


Fig. 2. Diagrammatic sketch of the lymphatics to show both deep and superficial systems as well as the main regional groups of lymph nodes. Note that the superficial lymphatics of the leg converge and enter the saphenous opening to join the deep lymphatics which then ascend along the iliac vessels to the thoracic duct.

gional networks, each passing through fixed groups of lymph nodes (Fig. 2). These nodes are composed of lymphocytic cells arranged along a labyrinth of channels, through which the lymph flows on its way centralward in gradually enlarging vessels, finally entering the thoracic duct which empties at the junction of the left jugular and left subclavian veins in the neck. A second, smaller duct drains into the right side and carries lymph only from the right upper extremity, right side of the neck, the heart, and the lungs. The lymphatics are thin endothelial lined channels equipped, as the veins, with valves.

The primary function of the lymphatic system is drainage of fluid from the tissue spaces. Especially significant in surgery is the drainage of fluid from areas of acute inflammation, and the transporting of bacteria and of cancer cells, thus playing an important part in the extension of infection and of cancer. The lymph nodes protect the body because they halt, for a time at least, further invasion. In the case of cancer, they act merely as a sieve, holding back the malignant cells for a while. With infection, however, their function is more useful; the cells lining the lymph spaces actively fight the invaders, and, indeed, in most cases succeed in killing them, thus protecting the rest of the body. In the process, the nodes always enlarge and sometimes soften and suppurate. The lymph vessels, although usually passive agents, are not infrequently involved in infections and become evident clinically by lymphangitis, lymphedema, and elephantiasis. The neoplastic diseases of lymphatic vessels and nodes are described in Chapter 20; the following discussion will therefore be confined largely to the inflammatory lesions.

THE LYMPHATIC VESSELS

Lymph flow from tissue spaces is always active but is slight in the resting limb. During acute inflammation it is often tremendous. Experimental studies by Field, Drinker, and White (3) have cast much light on lymph flow after immersion of the extremity in very hot water. Not only is the lymph pressure increased, but the protein content, normally under 1 per cent, rises to a value four times greater. The inability of the lymphatics to drain all of this exudate rapidly enough is probably responsible for the swelling in and even outside the actual field of inflammation (i.e., collateral edema) as discussed in more detail on page 597.

The lymphatics, like the veins, in the lower extremity at least, are composed of a deep and superficial group, separated by the deep fascia. Unlike the veins, lymphatics have no communicating channels through this barrier, although they do converge and join at

the saphenous opening below the inguinal ligament.

Trauma to Lymph Vessels. Such injury is probably frequent but is usually nonevident, for even if a large channel is cut, the lymph clots at once or the flow is so slow as to escape detection, especially if much bleeding is present. Detailed experimental studies by McMaster and Hudack (4), however, indicate that the tiny lymphatics severed by incisions remain open for as long as 48 hours and may absorb infectious material for this length of time. Later, however, they proliferate extensively into the inflammatory area (as described in a previous chapter) and play an important role in healing and repair. On rare occasions, clear fluid pours out of a wound profusely and for many days or weeks. Such an event is called *lymphorrhea* or *lymphorrhagia.* It is apt to be especially severe if the *thoracic duct* itself is torn as it enters the subclavian vein in injuries or operations in the left lower part of the neck. The escape of lymph into the pleural cavity or through the base of the neck (in the case of injury) may stop spontaneously; however, it usually requires such a long time that severe malnutrition may start before it ceases. Accordingly, operation is usually advisable to ligate the leaking lymph duct. Complete relief is afforded by ligation, and recurrence of leakage is uncommon. *Chylous ascites* is produced when the large lymph vessels of the mesenteries are injured, permitting their contents to escape into the peritoneal cavity.

After complete division of lymphatics to a limb, normal flow is soon restored as shown by the studies by Reichert (5). He found that regeneration of new channels is a rapid process, taking but a week in absence of infection.

Infection of Lymph Vessels. Even in severe infections the larger lymphatics usually play but a passive role in carrying exudate and occasionally bacteria from the inflammatory area. On some occasions, bacteria may gain access through a slight wound and be carried to the lymph node without provoking significant inflammation in either the skin or lymphatic channels. In such a case, the first defensive reaction takes place in the node.

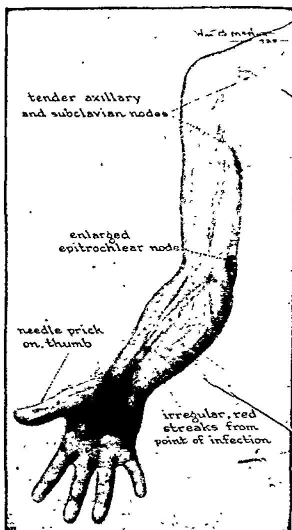


Fig. 3. Acute tubular lymphangitis. Streptococcus lymphangitis and lymphadenitis in a physician following a needle prick during an operation for appendiceal peritonitis. (From Babcock. Textbook of Surgery, W. B. Saunders.)

Acute Lymphangitis. Acute inflammation of the major lymphatics is called *acute tubular lymphangitis* (Fig. 3). It must be distinguished from the diffuse lymphangitis of the smaller channels. It is evident clinically as red streaks which extend up the arm or leg from the local portal of entry. It may be seen following relatively mild infections, and usually it is indicative of a serious invasion; it is frequently accompanied by the signs of systemic infection, i.e., chills, fever, and prostation. In such a case, the visable lymphatic vessels are intensely red, swollen, and often surrounded by an area of edema.

Tenderness is slight. Except in the severe or fatal cases, the process usually subsides in two to five days. However, the regional lymphadenitis, which so frequently follows lymphangitis, usually subsides more slowly. Occasionally the involved lymph nodes suppurate. Treatment of lymphangitis is strictly one of *noli me tangere* as far as operation is concerned; application of hot moist packs along the involved extremity will be helpful. The extremity, however, should be completely immobilized. Incision is used *only* if a local abscess forms along the course of the lymphatic; this rarely occurs. Chemotherapy has all but eliminated this formerly common condition.

Acute Diffuse (Reticular) Lymphangitis. This term is applied to a variety of infections. Its most specific and characteristic, though perhaps least common, form is a type involving the entire subcutaneous system of an extremity, which may occur in patients with lymphatic obstruction (lymphedema). Matas (6) has been influential in describing and emphasizing the importance of this type of lymphatic infection. It is ushered in by chills, fever, prostration, and a tender red swelling of the entire limb. A streptococcus has been found in many cases. After the infection has subsided completely, the swelling decreases, but a permanent enlargement persists due to the deposition of fibrous tissue and a continuing mild chronic lymphangitis (see below). Repeated attacks eventually lead to elephantiasis.

A more common type of reticular lymphangitis is that produced by a spreading infection which involves the smaller local lymphatic channels. Clinically, the redness, swelling, induration, and so forth, is differentiated with difficulty from acute cellulitis. Indeed, there undoubtedly is always a certain degree of diffuse reticular lymphangitis present in acute cellulitis. Entirely different is the reticular lymphangitis called erysipelas (see Ch. 7). Erysipeloid, however, is a mild type of reticular lymphangitis which occurs most commonly following injury to the skin of individuals who work with oysters or other types of sea food. Treatment is simple inasmuch as the infection usually subsides spontaneously, although chemotherapy is often helpful.

Another form of acute lymphangitis, still different, is the inflammation noted by Homans (7) around the iliac and femoral vessels in a patient with thrombophlebitis femoris, as already discussed (see Ch. 25).

Chronic Lymphangitis. Indolent, longstanding ulcers of the lower leg, often called stasis ulcers are usually associated with chronic lymphangitis. The skin surrounding the ulcer is thickened, inelastic, and discolored. These changes frequently precede ulceration. Occlusion of the cutaneous lymphatics has been demonstrated (8). The subcutaneous tissue is the site of edema and fibrosis which is believed to be due to chronic infection of the lymphatics through the open lesion. Chronic inflammatory changes about lymphatic vessels are occasionally due to the presence of a fungus (e.g., sporotrichosis) or of parasites (e.g., filaria) in the vessels. More commonly such changes are believed to be due to recurrent episodes of acute lymphangitis.

Chronic lymphangitis is seen, without obvious portals of entry for infection, in localized chronic swelling or enlargement, usually of the leg, often called lymphedema. Similarly chronic lymphangitis is also found with more pronounced swelling called elephantiasis. Histologically, there is primarily an extensive round cell infiltration of the finer subcutaneous lymphatic channels (Fig. 4). In addition, there may also be edema and fibrosis; the former, strictly speaking, is marked only in lymphedema, the latter only in elephantiasis. Unfortunately, microscopic study is possible only when the Kondoleon operation is performed and tissue is excised for examination. This is partly the reason, as indicated below, why there is confusion between lymphedema and elephantiasis. As might therefore be expected, the relation between chronic lymphangitis and its clinical manifestations are similarly difficult to establish.

Lymphedema. Lymphedema is a general term meaning a localized diffuse deposition of lymph in the skin and subcutaneous tissues, especially an extremity which is painless and which characteristically pits on pressure (Fig. 5). It occurs in a great variety of forms, acute and chronic. Acute lymphedema is common as an acute swelling, transient, usually associated with acute infections and

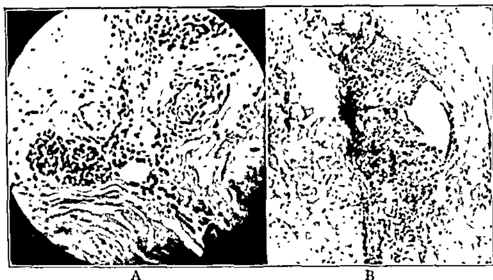


Fig. 4. Chronic lymphangitis. Photomicrographs from two cases of unilateral swelling of the leg in which the Kondoleon operation was done. A, note the round cell infiltration; only moderate fibrosis is present. The inflammation present in this case was not due to infection entering through ulcers of the leg for this patient had none. The onset of the swelling was insidious but there was a definite history of several attacks of acute infection (subcutaneous cellulitis) involving the entire affected leg; these attacks are characteristic of elephantiasis. B, note the dilated lymphatic vessel and extensive round cell infiltration; only moderate fibrosis was present. The inflammation in this case is probably similar in nature to that in A; there was a history of episodes suggesting acute infection of the subcutaneous tissues of the entire leg. The photograph of the leg is shown in Figure 8.

already described as collateral edema. Transient more or less acute lymphedema may also occur following insect bites and may be confusing if no history is obtainable and no wound discernible. The swelling, however, is apt to be somewhat harder and less apt to pit on pressure. This is also true of the lymphedema seen following thrombophlebitis femoris (see p. 587), in which the swelling also may only pit slightly on pressure, possibly because of the presence of lymphatic infection. Although the swelling in acute lymphedema is transient and of little clinical significance, it may, if extensive and acute enough, produce shock by dislocation of sufficient extracellular fluid into the swollen extremity.

Chronic lymphedema also occurs in a variety of forms (Fig. 6). The localized swelling is obviously different from the symmetri-

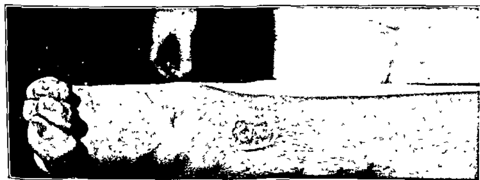


Fig. 5. Transient acute lymphedema secondary to a traumatic infected ulcer. The patient was a 37-year-old male. Note the pitting edema This swelling subsided promptly after several days of rest and elevation, and the ulcer healed. (St. Louis City Hospital.)

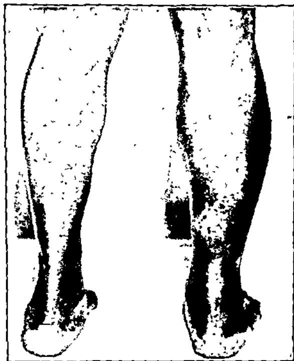


Fig. 6. Chronic lymphedema. The patient, a 59-year-old Negro, noted a gradually increasing swelling for one and a half years following a history suggestive of a venous thrombosis. Many months afterward the ulcers appeared, which are evident in the photograph although now almost healed following conservative care and elastic bandaging. The swelling pitted on pressure and decreased markedly on rest and elevation.

cal edema seen in cardiorenal disease and in hypoproteinemia, especially following the infusion of excessive salt solution (salt edema). Chronic lymphedema, to be discussed herein, is localized to one extremity or one part of the body and is due to regional lymphatic obstruction, to chronic lymphangitis, or more commonly to some unknown cause. There is a mysterious type of lymphedema which occurs commonly in young adults and represents a well-established clinical entity. When a hereditary factor is elicited, it is called Milroy's disease. In most cases, no history of trauma or hereditary tendency can be obtained and the term "lymphedema praecox" has been applied to them.

Injections of dyes and of radioopaque material for roentgenologic study into the lymphatics of the involved extremity show greatly dilated lymphatic channels and no evidence of obstruction (9). The swelling, usually confined to one leg or one arm, may subside completely on rest and elevation, the limb returning to its normal size. On ordinary use, however, the swelling recurs. Such an extremity is subject to infection of the lymphatics (reticular lymphangitis) which may lead to elephantiasis.

The group of chronic or persistent lymphedema shades off, as the disease becomes more severe, into elephantiasis. Indeed, there is considerable confusion in the use of the two terms. The term lymphedema should be confined to swellings which pit deeply on pressure and subside completely on rest and elevation. Chronic swelling, particularly when sufficiently advanced to be called elephantiasis, is probably due to chronic lymphangitis, as already indicated; diagnosis of this lesion depends, obviously, on microscopic section, particularly in patients with no history of infection and no ulcers or other obvious portals of entry for infection.

Treatment of acute lymphedema is often unnecessary, since the swelling subsides on removal of the cause. In chronic lymphedema, in the absence of a known etiology, effective therapy is difficult. Of greatest importance is the prophylaxis against recurrent infection which, as described above, will eventuate in elephantiasis. The factors which are conducive to recurrent infection are uncontrolled edema and trauma. The control of edema will also give symptomatic relief. This is best accomplished by the institution of a rigid regime consisting of the use of tightly fitting elastic bandages or stockings, applied only when the swelling has been relieved by an adequate period of rest and elevation. Usually, upon arising in the morning the swelling is gone, therefore the compression bandages are applied at this time. Scheduled periods of elevation during the day may be necessary and prolonged standing in one place is not allowed. Exercise in moderation is beneficial. The earliest symptom of an acute inflammatory episode is an indication for chemotherapy, rest, and elevation and immobilization of the extremity.

Elephantiasis. Elephantiasis is really different from lymphedema since the swelling is only partly due to edema, most of it consisting of actual hypertrophy of the skin and subcutaneous tissue because of fibrous tissue overgrowth. As the name implies, elephantiasis is a remarkable swelling or enlarge-



Fig. 7.



Fig. 8.

Fig. 7. Elephantiasis affecting both legs. The patient was a 50-year-old Negro. The swelling was insidious, without cause, beginning two years previously. It would diminish on rest and elevation, due presumably to a simple lymphedema of unknown etiology. The superficial ulceration noted in the photograph is of one year's duration and has been getting worse. The swelling now is brawny and hard, pits only slightly on pressure. After several weeks in bed the edema subsided to a moderate extent and the infection abated considerably.

Fig. 8. Elephantiasis affecting the left leg. The patient was a 14-year-old girl. The swelling was of insidious onset at the age of eight and became progressively worse, especially following mild attacks of a few days' duration, consisting of fever and redness, tenderness and pain in the leg. On admission the leg felt bulky on palpation and scarcely pitted on pressure. A Kondoleon operation was performed; a chronic lymphangitis was present in the excised tissue (see Fig. 4B). Although the patient was discharged with both limbs the same size, *the swelling recurred in the left leg and persisted (except for mild subsidence* during prolonged rest in bed). The case illustrates the difficulty in differentiating lymphedema from elephantiasis since it presents features characteristic of both.

ment which may affect an entire extremity, usually the leg (Figs. 7, 8), or in rare cases, the scrotum or vulva. Though more common in the tropics, it is seen everywhere, especially in *mild forms*.

The remarkable cases are usually seen only in the tropics. Though slight pitting edema is present, it disappears on rest and elevation, leaving a limb only slightly smaller than before, but indurated, somewhat pale and larger than its fellow. Occasionally, both legs are involved. Ulcers are present in some cases and, as already mentioned (Ch. 8), their indolence and lack of healing are no doubt due to the disturbance in lymph flow. Elephantiasis of the arm may follow radical breast amputation whenever the interruption of the lymphatics is associated with an infection; it has been designated by Halsted (10) as elephantiasis chirurgica (Fig. 9). The presence of fluid and fibrosis in the subcutaneous tissue can sometimes be differentiated by the study of soft tissue roentgenograms of the limb as pointed out by Reichert (11).

In the *pathogenesis* of elephantiasis, lymphatic obstruction plays a great role, but obstruction alone cannot explain the presence of the fibrous tissue overgrowth which is responsible for the greatest part of the enlargement. This is due, as pointed out by Matas (6) and also by Halsted, to a type of superimposed infection which is responsible for the deposition of fibrous tissue. In some patients, such infection (reticular lymphangitis) occurs in acute attacks with chills, fever, and prostration, the red swollen part finally subsiding and leaving an aftermath of diffuse fibrosis. It is after a history of many



Fig. 9. Elephantiasis chirurgica following removal of a fungating carcinoma of the breast six months previously. Note the tremendous swelling of the arm and hand. Usually, edema of the arm following radical excision of the breast is due to infection involving lymphatic vessels and veins. However, in this instance the condition is complicated by the enormous mass of recurrent carcinomatous tissue in the axilla. (Courtesy, Dr. J. W. Gale.)

such episodes that the limb finally attains a huge size. In other instances, the infection is more chronic, due, sometimes, to the presence of an indolent ulcer which acts as a permanent portal of entry, or occasionally to less evident infection. That lymphatic stasis by itself cannot cause elephantiasis is shown by the study of tropical elephantiasis in which filarial obstruction of the lymphatics has been erroneously assumed to be the sole causative factor. As pointed out by Matas, many patients infected with filaria do not have elephantiasis; conversely, in many patients with elephantiasis, no organisms can be found. Moreover, in those having elephantiasis with demonstrable filaria a history can often be obtained of recurrent acute attacks of the above-mentioned reticular lymphangitis from which a streptococcus has been isolated. Thus, it is clear that even in filarial elephantiasis it is necessary that infection as well as obstruction to the lymphatics occur before the disease is produced. Either alone will not lead to the disease.

Lymphatic infection and obstruction act together since the fibrosis which follows infection in itself obstructs a free lymphatic drainage. A vicious circle is thus doubtlessly established. Lymphedema is the primary event; secondary infection leads to fibrosis which interferes with lymph flow. This, in turn, leads to lymphedema which most likely renders the part less able to resist further infection. Such a conception of the dual role of lymphatic infection and obstruction is confirmed by the striking experiments of Drinker, Field, and Homans (12) who have produced lymphedema and elephantiasis in dogs by inducing lymphatic obstruction of the extremity which, in the successful experiments, was accompanied or induced by infection, streptococcal in nature. Typical fibrous tissue overgrowth was noted.

Treatment. Therapy based on the dual pathogenesis mentioned above is often quite efficient. Infection is first guarded against by avoiding injuries of any kind. Infection which may already be present, i.e., ulcers and indolent wounds, are treated by elevation, rest, hyperemia, and chemotherapy. Large ulcers may require excision and skin grafting. The progress of the disease may sometimes be halted in this way by closing the portals of entry for chronic infection in spite of the existence of a certain amount of lymph stasis. For those patients in whom recurrent infection occurs despite prophylactic measures, for intractable persistent or recurrent leg ulcers, and for the massive fixed enlargement, surgical treatment is indicated. The operative treatment of elephantiasis was at first directed toward efforts to provide new lymphatics to replace those which were obstructed or to by-pass the obstruction by creating anastamotic channels between the deep and superficial systems. The procedure described by Kondoleon in 1912, consisting of the excision of strips of skin, subcutaneous tissue, and deep fascia from the lateral and medial side of the extremity was based on the latter and has had the greatest clinical trial. It is now believed that the good results claimed for this operation are due to the prolonged period of bed rest and to the reduction in size achieved by the excision of tissue mass, rather than to effective improvement in lymphatic drainage. The many modifications of this procedure which have been de-

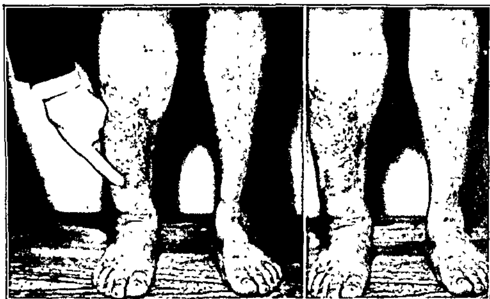


Fig. 10. Lymphangiectasis. The photographs were taken a few seconds apart. Note the compressibility of the swelling which is not due to a pitting edema; release of pressure as shown on the right results in an immediate return of the compressed point to normal. A portion of tissue which was removed showed dilated lymph channels as well as areas resembling hemangioma.

scribed have consisted of increasing the volume of excised scarred hypertrophied, edematous skin and subcutaneous tissue. Currently, good results have been obtained by the complete excision of skin, subcutaneous tissue, and deep fascia and covering denuded muscle with split thickness skin grafts obtained from the excised skin (13, 14). This procedure is done in one stage, using a pneumatic tourniquet to reduce blood loss during the excision. Operation is always preceded by a period of several weeks during which chemotherapy is administered and the limb is elevated and kept at rest to diminish infection and lymph stasis as much as possible.

Lymphangiectasis. Although often used synonymously with lymphangioma, lymphangiectasis is distinctly different because it is in reality not a true neoplasm. Lymphangiectasis consists primarily of dilatation of the lymph vessels and is commonly a sequela of lymph stasis (Fig. 10). A differentiating clinical feature lies in the fact that lymphangiectasis is compressible whereas lymphangioma is not. Small, localized areas are frequently encountered in the intestinal mesentery in association with carcinomatous metastases, but extensive lesions are perhaps most common in association with varicose veins of the legs. Transition from lymphangiectasis to a true neoplasm (lymphangioma) does occur, however, thereby accounting for considerable clinical and pathological confusion between the two lesions.

Treatment consists of excision of the involved tissue.

Neoplasms of the Lymph Vessels. Neoplasms confined to the lymph vessels are not common; the various types of lymphangiomas (e.g., cavernous lymphangiomas and cystic hygroma) are the most important in this group. They are discussed in Chapter 20.

LYMPH NODES

Knowledge of the various regions of the body draining into each of the many groups of lymph nodes helps considerably in finding the source of many apparently spontaneous lymph node enlargements which are seen by the physician. The superficial nodes are located in the subcutaneous tissue of the following areas and go by these names: cervical, occipital, axillary, epitrochlear, inguinal, femoral (subinguinal), and popliteal. The deep nodes include, among others, the iliac, mesenteric (abdominal), and thoracic (me-

diastinal) groups. In general, the two groups are separated by the deep fascia; they join, however, before they empty into the main lymph channels which enter the venous system by way of the thoracic duct.

The following inflammatory diseases affecting these nodes will be considered: acute lymphadenitis, chronic pyogenic lymphadenitis, tuberculous lymphadenitis, and syphilitic lymphadenitis. Only localized lymphadenitis will be considered because generalized lymph node enlargement is usually a manifestation of systemic disease which is nearly always of medical rather than surgical interest.

Acute Lymphadenitis. Acute infection of the lymph nodes is always regional and secondary, therefore, to inflammation in the area drained by them. Bacteria, however, may invade through a portal of entry which, for some reason, exhibits no inflammatory signs. Thus, the local lesion may be prominent and severe, or it may be hardly noticeable. In either case, the node serves as a barrier to prevent further invasion of the body. The effectiveness of the lymph nodes in removing bacteria entering them has been shown in perfusion experiments reported by Drinker, Field, and Ward (15). They found that no organisms were able to pass through the lymph node, at least during the early stages of inflammation. Specific antibodies may be produced in lymph nodes which, therefore, also play a role in resistance against the invasion of infection in an immunological manner. During the process of acute reaction the node enlarges, not only because of edema and exudation but also because of the multiplication and infiltration of phagocytes and other leukocytes.

Acute lymphadenitis is most commonly due to the invasion of bacteria of the pyogenic group such as staphylococcus and streptococcus, but in certain locations to Ducrey's bacillus, the *Bacterium tularense,* and the virus of venereal lymphogranuloma, as discussed in Chapter 7. The lymph nodes most commonly invaded are the cervical and axillary group and those in the groin, i.e., the inguinal and femoral nodes (Figs. 11, 12). The cervical nodes are perhaps the most fre-



Fig. 11.



Fig. 12.

Fig. 11. Acute cervical lymphadenitis. After two weeks of conservative care the swelling became fluctuant and was incised. On culture a streptococcus and staphylococcus were recovered; healing was uneventful but delayed. No portal of entry for the infection was found in spite of careful search of the oral and pharyngeal cavity.

Fig. 12. Acute axillary lymphadenitis. Two weeks after onset the swelling was incised. A hemolytic streptococcus and staphylococcus were isolated in this case. Ten days before the node began to swell, the patient injured the index finger with subsequent transient superficial infection.

quently infected, following acute infections of the oral cavity, including such upper respiratory infections as pharyngitis and tonsillitis, and also dental abscesses. In the latter case, however, it may be the deeper tissue of the neck rather than the superficial lymph nodes which become infected and swollen. The clinical picture as described below has been greatly modified by the advent of chemotherapy. For reasons mentioned before, the original description will be retained.

Clinical Manifestations. Acute lymphadenitis may become evident as early as 12 to 24 hours following the entrance of bacteria at the portal of entry. As stated already, however, there may be no evidence of inflammation at the primary site or in the channels which transmit the offending organism. Enlargement of the affected node, accompanied by local heat and tenderness occurs early. As the enlargement progresses, pain and disability of variable extent soon follow and become progressively more marked. For example, a severe *cervical lymphadenitis* provokes so much pain and discomfort that the patient may be unable to turn his head from side to side. In severe cases, fever will be noted early; its degree will depend, of course, on the severity of the infection. Accompanying the fever may be other symptoms, such as general malaise, weakness, anorexia, and prostration. After a day or two, the tissue about the lymph node will become swollen and edematous (periadenitis). As the infection proceeds, neighboring nodes are apt to become involved. These nodes are at first discrete but later become confluent. In a few days, redness of the skin over the involved nodes begins to appear; this usually indicates suppuration and is frequently produced by the escape of pus into the subcutaneous tissues through rupture of the capsule of the infected nodes. However, in a majority of instances, acute lymphadenitis is a transient process and subsides rapidly without suppuration as soon as the primary infection is overcome. It usually takes several days, however, before the node recedes to its normal size. In adults, this is the usual outcome; in children, however, suppuration is more frequently encountered.

If suppuration occurs, the pain persists and usually increases. Fluctuation will be demonstrable in most instances except when the node is deeply seated. In such a circumstance, suppuration will be suggested by the continued fever and local pain. Occasionally, deep suppuration is accompanied by a variable degree of overlying cellulitis as the undrained abscess breaks through the capsule of the node into the surrounding tissues; there is, however, a distinct tendency for the pus to remain localized and point outward toward the skin.

Septicemia may follow should the infection break through the line of defense within and around the lymph node and enter the general circulation. This is particularly apt to occur when the causative organism is a hemolytic streptococcus arising from an upper respiratory infection (Fig. 13). In such instances, a more serious outcome may occur, as has already been discussed under Septicemia.

The local manifestations of *inguinal lymphadenitis* may be confused with strangulated inguinal hernia. The disability and local pain produced may be the same. However, an important differential feature lies in the fact that the development of the local manifestations produced by infection is gradual, whereas those associated with a strangulated hernia appear suddenly. If there is any doubt as to the nature of the swelling, a careful search should be made of the area drained by the nodes, i.e., the perineum, the anus (e.g., infected fissures), and the genitalia. The primary lesion may be merely a small scratch, an infection about a hair follicle, or a tiny ulcer under the foreskin. Occasionally, the diagnosis is made only at operation.

Infection of *retroperitoneal or deep inguinal (iliac) lymph nodes* may simulate local peritonitis or, if on the right side, acute appendicitis. This diagnostic confusion is particularly likely in the early stage before the node has enlarged sufficiently to become palpable. Fever is higher, but vomiting less likely, in lymphadenitis. Children are much more commonly infected than adults. When a mass is palpable, it is usually felt under Poupart's ligament or in the lower abdomen just above the ligament. In the latter location, it may be impossible to differentiate from appendiceal abscess. The portal of entry for these infections is seldom demonstrable. A number of such cases have been well de-



Fig. 13. Acute cervical lymphadenitis due to a hemolytic streptococcus. The patient was a three-year-old child. During the course of over two months five of such abscesses formed and were incised for drainage, each time yielding the same organism in pure culture. The child had otitis media, pharyngitis and a streptococcus osteomyelitis. Recovery was finally complete. This type of cervical lymphadenitis (produced by the hemolytic streptococcus) which occurs so frequently in children following otitis media, etc., is particularly prone to persist for many weeks before subsiding. Chemotherapy, however, often hastens final healing.

scribed by Irwin (16). Operation for incision and drainage is usually indicated.

Acute lymphadenitis in other parts of the body may produce local effects which may or may not be characteristic. *Mesenteric lymphadenitis* is not uncommon in children and may simulate peritonitis, as discussed in Chapter 32. *Mediastinal lymphadenitis* is described in the chapter on Surgical Diseases of the Thorax.

Acute lymphadenitis may last from one to two weeks except that, if suppuration demands incision, the sinus may require longer to heal. However, there is a type of acute cervical lymphadenitis in children secondary usually to pharyngitis, otitis media, and mastoiditis, which before the days of chemotherapy used to persist for many months and require incision at intervals because of successive involvement and suppuration of various nodes. This type of infection is encountered chiefly in winter and sometimes in an epidemic form. Systemic manifestations, such as fever, malaise, weakness, anorexia, and tachycardia, are particularly apt to be present. A fever may persist every day for weeks, or may recur intermittently, apparently as new lymph nodes become involved and suppurate. The offending organism in these cases is usually the hemolytic streptococcus, or less commonly, the hemolytic staphylococcus. This type of infection is becoming rare.

Treatment. The treatment of acute lymphadenitis is the same as that of acute infection in general, as already discussed in previous chapters; chemotherapy is very helpful. Rest of the affected part is obviously necessary. For example, a patient with axillary adenitis should carry the arm in a sling in order to prevent massage of the infected nodes by motion of the arm; if the infection is severe, bed rest may be advisable. Cervical and inguinal adenitis also justify bed rest, particularly if fever is present. The primary site of infection producing the lymphadenitis should receive early attention; immobilization, application of hot wet packs, and incision of abscesses when they form are indicated. Tonsils and teeth are prone to cause cervical adenitis, particularly in repeated attacks; if such a history is obtained, the tonsils and offending tooth or teeth should be removed, *but only after all the evidence of acute infection has subsided.*

Chemotherapy, if started early, will prevent suppuration. Often, however, suppuration may develop insidiously and be difficult to detect during chemotherapy, for reasons already discussed. However, the nodes should be examined daily for the development of fluctuation; when found, incision and drainage is indicated without delay. When doubt exists as to the presence of pus, aspiration may be utilized as a method of diagnosis, but not if the nodes are deeply situated and lie adjacent to the large vessels of the neck; the danger lies more in the production of an infected thrombus by puncture of a vein, than in producing hemorrhage. Occasionally, when *fever persists for days, and local tenderness is* marked, exploration of the deep nodes will be justified; in such instances the surgeon is usually rewarded by finding pus in one of the nodes (see also section on deep cervical infections in Chapter 31). A change in the chemotherapeutic agent based on sensitivity tests of the isolated organism may be decisive.

Chronic Pyogenic Lymphadenitis. Slight enlargement of lymph nodes occurs frequently as a result of chronic or recurrent mild pyogenic infections of low grade virulence in the field drained by the nodes. Such infections are commonly seen in active boys who frequently injure their extremities, so that the resulting mild infections produce a moderate painless enlargement of the femoral and axillary nodes. The cervical region is also a common site because of the frequency of mild repeated or chronic respiratory infections. Chronic pyogenic lymphadenitis of this type has little clinical importance except for the fact that it is often mistaken for tuberculosis or malignant disease. Removal of one of the nodes for microscopic examination is usually necessary to solve the diagnostic difficulty. When possible, of course, the primary infection responsible should be investigated and eliminated.

The sinus produced by the drainage of an acute lymphadenitis persists in rare instances and the associated lymph nodes remain enlarged and palpable. In such an event, total excision of the sinus and involved nodes may be indicated; such an operation rarely results in any spread of infection and is almost always curative. In many cases, the question of whether the infection is tuberculous or not is impossible to answer on clinical evidence alone; microscopic examination of the excised tissue will nearly always result in a positive diagnosis.

Tuberculous Lymphadenitis. Though none is exempt, tuberculosis most commonly involves the cervical and mediastinal lymph nodes (Fig. 14). The portal of entry for the cervical nodes is believed to be in the oral or pharyngeal cavities, but it is seldom if ever detectable. Cervical involvement is seldom encountered as part of a systemic (pulmonary) infection. Tuberculous lymphadenitis is probably due to the bovine type of the bacillus. In the United States, at least, it has *therefore all but disappeared due to the* elimination of tuberculous milk following the rigid inspection of cows for the presence of tuberculosis and the general use of pasteurized milk in the cities.

The disease first causes infiltration of endothelial and giant cells or actual tubercle formation, which brings about a simple hypertrophy of the node. Softening or caseation may occur by the gradual breaking down and digestion of tissue by the organism or its products. Tuberculosis is also prone to lead to a deposition of calcium in the node, especially when caseation occurs. Spontaneous drainage of such softened lesions is not infrequent. The calcareous deposit in such instances acts as a foreign body and may lead to the formation of a permanent sinus until the calcified node is removed surgically.

The nodes in the early stages are moderately enlarged, firm, elastic and not tender. When several are involved they are discrete, though as they enlarge they may coalesce. They may remain in a chronic stage of enlargement indefinitely, and gradually subside or soften. Should the tuberculous nodes suppurate, the fluctuant mass is called a *cold abscess,* because it is without acute inflammatory signs. These may open spontaneously or be incised. The pus is usually thick and creamy but may be thin and watery and contain caseous particles. The resulting wound frequently fails to heal and becomes a chronic draining sinus or indolent ulcer. A positive tuberculin test is of diagnostic value only in young children.

Treatment. Systemic therapy may be indicated, especially with the tuberculostatic



Fig. 14. Tuberculous lymphadenitis. The photomicrograph is of a lymph node removed from the neck of a young woman whose only complaint was of the small mass of six months' duration. There was a history of transient pleurisy some years previously, which may have been tuberculous. Note the tuberculous tissue in the midst of normal lymphoid cells. Giant cells are obvious and there is considerable necrosis although caseation is not as pronounced as it often is (see Fig. 17, Chapter 7). No other evidence of tuberculosis was found in this patient, who remained perfectly well.

drugs. Local treatment depends upon the presence or absence of fluctuation and a *chronic draining sinus*. 1. *When no fluctuation* is present, treatment may be merely symptomatic and hygienic. Excision has the advantage of actually removing the tuberculous focus and of insuring a definite diagnosis by microscopic and bacteriologic study of the tissue. Radiotherapy often results in a subsidence and even disappearance of the swelling (Figs. 15, 16). In any case, removal of one of the more superficial nodes is advisable to establish the diagnosis before beginning treatment. 2. When the node is fluctuant, repeated aspirations may forestall its opening spontaneously, but may occasionally lead to the development of a chronic draining sinus. However, if spontaneous drainage is imminent, it is better to open the abscess with an adequate incision to obtain free drainage. Excision of all of the diseased tissue will, however, *result in the most rapid healing and* is often preferable. 3. When chronic draining sinuses do occur, healing will frequently be hastened by radiotherapy. However, a careful excision of the sinus and its attached node, which is frequently calcified, will usually save *months of care and lead to much more rapid* healing, even in the face of an open secondarily infected wound. Moreover, a positive diagnosis is thus possible (by microscopic section and bacteriologic studies).

Syphilitic Lymphadenitis. Enlargement of the lymph nodes is constantly associated with the primary and secondary stages of syphilis. Within a few days or weeks after appearance of the primary lesion, the nodes draining the area become discretely enlarged and firm, but do not suppurate unless secondary infection develops. When the secondary lesions of the disease appear, there is apt to be a generalized lymphadenopathy. This is more pronounced in the Negro race than in the white. Differentiation from tuberculous lymphadenitis is rarely difficult because syphilitic nodes are apt to be generalized at some time in the disease *and do not suppurate*; the Wassermann reaction is of value after the primary stage.

Neoplasms of the Lymph Nodes. The inflammatory lesions, as just described, consti-



Fig. 15. Chronic cervical lymphadenitis, probably tuberculous. Note the mass on the left side, which, during two months, had grown slowly in size, was not tender or painful but finally became fluctuant. A small amount of thick pus was aspirated which showed only lymphocytes and no bacteria on smear, yielded no growth on culture and did not produce tuberculosis after injection into a guinea-pig. Oral cavity, nose and throat revealed no source for the infection. The swelling disappeared following radiotherapy, and the patient has remained well.



Fig. 16. Healed tuberculous lymphadenitis of the neck. The patient was a 27-year-old woman. For five years at intervals small nodes would appear, enlarge and suppurate without pain or tenderness (cold abscess). Tubercle bacilli were demonstrated on smear of this pus. With the aid of radiotherapy healing has always occurred. The patient has evidence of a quiescent pulmonary lesion. A few nodes one to two centimeters in diameter are still present, and may be seen above the scars of the healed sinuses.

tute the most common causes of enlargement of lymph nodes. The neoplasms affecting the lymph nodes are discussed in detail in Chapter 20. Almost all of them are malignant either primary or metastatic.

Lymphatic leukemia may or may not be considered as a true neoplasm; it is characterized by a generalized enlargement of the lymph nodes; there is an associated lymphocytosis of the blood. The nodes remain discrete and do not adhere to the skin or ulcerate. Microscopically, the node is composed of a finely reticulated tissue, which is densely infiltrated with small lymphocytes. An acute form is commonly encountered in children and is rapidly fatal; the illness consists of the appearance of soft, discrete lymph nodes, anemia, and hemorrhages beneath the skin and from the mucous membranes; it may terminate in death within a few days. The chronic form occurs chiefly in adults and is characterized by remissions of anemia, weakness, enlargement of the lymph nodes, and lymphocytosis. An aleukemic form, characterized by an absence of leukocytosis but a relative increase in the lymphocytes of the blood, is also encountered. The leukemias, including the myelogenous type, are primarily medical diseases but may be of surgical interest initially, at least, when diagnosis is uncertain. Microscopic examination of an excised node will nearly always remove any doubt.

DIFFERENTIAL DIAGNOSIS OF TUMEFACTION OF THE NECK

The cervical region is perhaps the most frequent site of tumefaction in the body. Whether small or large, these swellings always present a difficult diagnostic problem. Most of them are lymph node enlargements; many are due to acute or chronic inflammation. There are many other lesions, neoplastic and congenital, which occur often enough to add to the diagnostic possibilities. The history and complete physical examination are of primary importance. A detailed chart containing a list of the most common types of tumefaction, whether of the neck or of other parts of the body, will be found on the following page.

Special Features in Examination. 1. Careful examination of the areas drained by the cervical lymph nodes should include the scalp and the oral and pharyngeal cavities. In the latter case special laryngeal mirrors are necessary to inspect all the possible sites for ulcer, tumor, chronic infection, and so forth. Search is also made for sinusitis and infections about the teeth.

2. The Wassermann or Kahn reaction is of value in the diagnosis or elimination of secondary and tertiary syphilis.

3. The tuberculin test, if positive, is of value only in children, chiefly in the very young. A negative test is of value at any age; however the test is so frequently positive in older children and adults that it is not even used on them.

4. Aspiration of fluctuant tumors will give valuable information provided the lumen of the needle is large enough to convey the contents, which sometimes are viscid and thick. Pus should be smeared, stained, and also cultured. If tuberculosis is suspected, some of the pus should be injected into a guinea pig. If nothing can be aspirated, the fluid is either too thick, i.e., contains sebaceous or fibrinous material, or the mass is a solid tumor, i.e., a nonsuppurating lymph node, lipoma, lymphangioma and the like. Aspiration should not be used deeply below the surface because of the danger of entering the large vessels of the neck. Biopsy by aspiration with a needle is an effective diagnostic mechanism in detecting cancer, but at times it may disseminate the cancer.

5. Excision of tissue for microscopic study is usually the most decisive of all diagnostic procedures. If at all possible, the biopsy should be excisional, not incisional, to avoid or minimize dissemination of cancer cells. In many cases, the operation also serves the purpose of ridding the patient of the entire lesion. In removing a lymph node, it is wise to divide the specimen in two parts, sending half of it for microscopic study and preserving the other half in a sterile container (Petri dish) in the refrigerator. Should the histologic examination show a nonspecific type of inflammation, the remaining tissue can then be subjected to various bacteriologic procedures aimed at isolating a causative organism.

Tumefaction of Lymph Node Origin. These comprise both inflammatory and neoplastic lesions and have been described in detail elsewhere. It should be emphasized that

CHART 1

COMMON TYPES OF TUMEFACTION

* Lesions likely to occur in the neck.

a distinctive feature of inflammatory lymph node enlargement is the *periadenitis* which is generally absent in neoplastic disease. However, chronic enlargement of cervical nodes in children are frequently seen with very little periadenitis, and central necrosis plus secondary infection may result in marked periadenitis in the metastases from cancer primary in the oral cavity.

(*a*) Acute lymphadenitis, because of its marked local manifestations, very rarely offers any diagnostic difficulty.

(*b*) Chronic pyogenic lymphadenitis is due to low grade or recurrent pyogenic infection whose source is searched for in the area drained by the nodes. If suppuration occurs, the pus usually shows pyogenic bacteria on smear; cultures, however, may be negative because the organisms are dead.

(*c*) Cold abscess is often due to a tuberculous lymphadenitis which has suppurated. However, it may be a manifestation of caries of the cervical spine (Pott's disease). Local examination and lateral x-ray of the spine is important.

(*d*) Tuberculous lymphadenitis has no demonstrable portal of entry, and is characterized by a painless, moderately soft swelling, consisting of nodes which at first are discrete but later become matted together. Biopsy reveals giant cells, tubercles, and the like. Tuberculous pus, when present, may not show the organisms on smear, but should produce the disease in guinea pigs. In young children, a positive tuberculin test is of considerable significance.

(*e*) Metastatic carcinoma (Fig. 17) is undoubtedly the most frequent cause of malignant disease of the lymph nodes, particularly in old people. The nodes are firm, not tender, and ultimately become fixed to adjacent tissue. In the superior portion of the neck, lymph node enlargement due to metastatic cancer commonly has its origin from epidermoid (squamous cell) cancer arising in the oral cavity, pharynx, or nasopharynx, although epidermoid cancer arising in the skin of the face or head, particularly in the region of the ear, may be the source. It is therefore of great importance to make a thorough search of these areas for a primary tumor in older patients who have a mass in the upper neck. In young women, persistent lymph node enlargement in the neck should suggest the

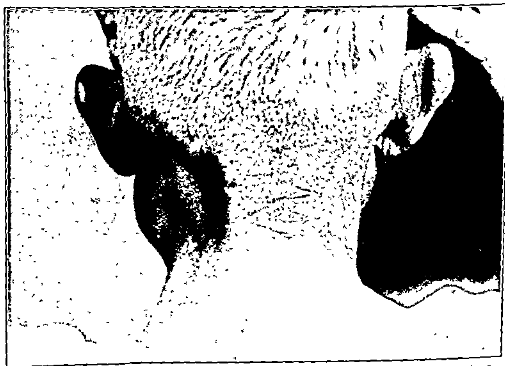


Fig. 17. Metastatic carcinoma of the cervical lymph nodes. This patient, a 59-year-old farmer, first noted a painless swelling in the left side of the neck. Later salivation developed. An extensive ulcerating carcinoma of the left tonsil was seen on inspection of the oral cavity. This patient is a suitable case for radiotherapy, preferably with the fractionated Coutard technic.

possibility of carcinoma of the thyroid, even in the absence of a palpable thyroid tumor. In the lower neck, bronchogenic carcinoma is a frequent precursor of right supraclavicular lymph node enlargement, while carcinoma of the stomach or colon metastasizes more commonly to the left supraclavicular lymph nodes. Biopsy in most cases will be necessary except in patients in whom there is a primary lesion in the oral cavity, in which case biopsy will likewise be indicated. Under such circumstances, a radical neck dissection will be indicated and is often curative.

(*f*) Hodgkin's disease (Fig. 18) and lymphosarcoma are often diagnosed with certainty only after the study of an excised node although, in a few cases, the differentiation from nonmalignant lesions will be impossible. In such a case, subsequent biopsy later in the course of the disease may be diagnostic. The enlarged nodes are usually discrete and periadenitis is absent.

(*g*) Leukemia produces a diffuse lymph node enlargement which shows typical histological features; the blood usually shows characteristic changes.

(*h*) Mild enlargement of the cervical nodes, as part of a generalized lymphadenopathy, is encountered as a systemic manifestation of syphilis. On rare occasions, the lymphadenopathy which accompanies a chancre of the lip is a source of diagnostic difficulty. Generalized lymph node enlargement is usually due to a variety of medical diseases, such as infectious mononucleosis and serum sickness.

Tumefaction Not of Lymph Node Origin. (*a*) Benign neoplasms of the skin and subcutaneous tissue, such as lipoma, fibroma, lymphangioma, and nevus, usually present no special diagnostic problem. Aneurysm and arteriovenous fistula are likewise easily detected by their local manifestations.

(*b*) Congenital cysts are rare; they may be



Fig. 18. Hodgkin's disease before and after radiotherapy. The patient was 11 years old. The diagnosis was based on biopsy at the site shown in the left photograph. The patient also had a palpably enlarged spleen, irregular fever, slight anemia and a leukocytosis of 19,000 to 23,000. The photograph on the right was taken three weeks after the one on the left, following a course of radiotherapy; the mass disappeared entirely shortly afterward as did the enlargement of the spleen. Recurrent tumors of the neck and axilla occurred three years later, which likewise responded to radiotherapy. The patient was asymptomatic for eight years when he became anemic because of persistent melena due apparently to bleeding from the stomach, which disappeared spontaneously. The patient, now aged 33, is married, has two children and is apparently free of disease 22 years after its onset. Such long survivals are seen only in a small percentage of cases.

of branchial cleft origin if on the lateral side, or of thyroglossal duct origin if in the midline. The cyst may be a part of a lymphangioma (hygroma). The fluid is clear (colorless or straw colored), unless infection is present. Fluid of a branchial cyst is turbid, and grossly could be confused with purulent fluid of cold abscess. Pathognomonic findings in the branchial cyst are the presence of cholesterol crystals.

(*c*) Sebaceous cysts are not common in the neck but present no diagnostic difficulty.

(*d*) Dermoid cysts are likewise uncommon and are often confused with branchial cleft cysts.

(*e*) Carotid body tumor is rare and slow-growing but is usually diagnosed only during or after excision.

(*f*) Tumors of thyroid origin (adenoma, hyperplasia) are characteristically in the normal position of the gland.

(*g*) There are innumerable miscellaneous lesions, many of which are common and important. Actinomycosis and mixed tumor of the parotid are often considered in the differential diagnosis of cervical tumefaction, but they really involve the lower portion of the face and jaw and thus are, strictly speaking, not of cervical origin. Swelling of the submaxillary gland is rare but is most often due to obstruction of the duct by a stone. Acute tumefactions, such as Ludwig's angina and deep cervical abscess, have such striking manifestations as to rarely cause any diagnostic difficulty.

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27

THE NERVOUS SYSTEM

W. Eugene Stern

Peripheral and Cranial Nerves
The Brain
Affections of the Spinal Cord
The Autonomic Nervous System

From the regional standpoint the nervous system may be classified into: 1. the peripheral and cranial (somatic) nerves; 2. the brain and spinal cord; and 3. the autonomic (sympathetic) nervous system.

PERIPHERAL AND CRANIAL NERVES

Anatomically the nerve is composed of nerve fibers, the number of which decreases by branching as the terminal end is approached. Each fiber is in reality the axon of a nerve cell. The cells of the motor nerves are located in the brain and spinal cord, whereas the cells of the sensory nerves are in the specialized cranial and spinal ganglia.

Injury. When the continuity of a nerve (motor or sensory) is destroyed, all nerve function distal to this point is lost. Following an anatomic division, a peripheral *degeneration* of the nerve occurs. This process, named Wallerian degeneration after its discoverer, consists of fragmentation and absorption of the myelin and the axis cylinder, leaving the sheath of Schwann sufficiently viable and patent to receive a new fiber regenerating from the central stump. Retrograde degeneration may progress proximally for short distances, and reversible chromatolysis may occur in the cells of origin.

Regeneration of the severed nerve takes place from the central stump and, if there is no obstructive barrier, the axis cylinders find their way into the distal stump. Growth is slow, averaging perhaps less than 3 mm. per day and is influenced by the distance of the injury from the cells of origin, the rate being greater the more proximal the injury. A physiologic connection of the end of the nerve and its end organ requires an additional amount of time. The time required for regeneration and return of function even under favorable conditions varies considerably, as mentioned below. Injury may sever the axis cylinders but spare the Schwann tubules in which case the regenerating axons grow into their own tubules and excellent functional return occurs. Physiologic block of conduction may occur in closed blunt injuries without any anatomic interruption of nerve elements. Functional recovery is rapid and complete in such circumstances.

The types of injury vary, but the most common lesion responsible for complete loss of function is severance of the nerve by an incised or lacerated wound, or by avulsion. Other injuries are those produced by stretching or pressure; these may be followed by total, though perhaps temporary, loss of function. It is possible to stretch the brachial plexus or avulse the spinal nerve roots by extreme force applied to the shoulder, neck, or upper extremity. In fractures, nerves may also become pinched by fragments of bone or be compressed by callus. Injury to the radial nerve by a fracture of the humerus is the most frequent example of this type. Another type of paralysis is the so-called tourniquet paralysis; it occurs in extremities and results from the application of a tourniquet too tightly or over too long an interval. Such paralyses are usually of a temporary nature but on rare occasions recovery takes place only after re-



Fig. 1. Brachial plexus injury. Late stage of severe injury to the brachial plexus. Note the muscle atrophy, the fixed posture, and the taut, shiny skin of autonomic paralysis which accompanies the sensory and motor paralysis.

generation of the nerves. A physiologic block of nerve conduction without loss of nerve continuity may be produced by blunt injuries or pressure, and thus simulate anatomic interruption. Characteristically, motor function is more severely affected than sensory function in such injuries. A careful history of the mechanism of injury is required to assess correctly the probable underlying pathologic process and its surgical implications. A stretch injury may be anatomically complete, just as an open division of the nerve, but in the former the injury is longitudinally extended over many centimeters of the nerve trunk. In the case of closed brachial plexus injuries—as so often is seen in auto accidents—the distinction between root avulsion from the spinal cord and plexus stretch may not be readily made by careful muscle and sensory examination (Fig. 1). Specialized histamine skin tests (axon reflex) and cervical myelography may be helpful in separating the two mechanisms.

Complete severance of sensory fibers is followed by immediate anesthesia of the skin over the area supplied by the nerve, except for the margin of the area where overlapping of adjacent nerves will maintain partial function. This partial function is shown by retention of some sensation (i.e., sensibility to pin prick) in this zone, although the sensibility to light touch is lost. Deep sensibility and the sensation of position of joints and digits may be retained over the entire anesthetic area, because this function is usually ascribed to a different set of fibers which are present to a large extent at least in motor nerves. The area of sensory loss of pain and temperature is greater in the early stages after section of the nerve than it is later. The area of anesthesia decreases long before regeneration has occurred; this results from the assumption of function by the overlapping nerves and must not be confused with recovery of the injured nerve.

The anesthetic skin is apt to be dry, due to denervation of the sweat glands, and the nails become brittle and frequently deformed. Tapering of the fingers and atrophy of their pulp also occur. Important is the likelihood of unconscious infliction of trauma, such as burns, because of the anesthesia; the patient, therefore, must be cautioned about this danger.

An incompletely severed sensory nerve is followed by less definite disturbances of function. Sensation may be merely diminished (hypesthesia). There is usually considerable tingling and burning (paresthesia) over the area which may likewise be extremely sensitive to touch (hyperesthesia) or exhibit painful hypesthesia. Causalgia is a syndrome occurring occasionally after incomplete damage to nerves with a large sensory component (commonly the median and tibial nerves). It is characterized by intense, constant, burning pain, which is aggravated by emotional and psychic stimuli. Wet applications are helpful. Blocking of the sympathetics with a local anesthetic is a useful diagnostic and therapeutic tool, and it may support appropriate sympathetic denervation as effective therapy for this painful debilitating syndrome.

Complete severance of motor fibers is followed by immediate loss of the power of voluntary contraction in the muscle innervated. Electromyographic examination of the paretic muscles will in from 7 to 18 days, de-

pending on the nerve involved, demonstrate denervation fibrillation potentials and represents an important diagnostic finding. Contraction to faradic current stimulation is at first possible, but after a few days even this is lost. Contraction to galvanic current also takes place, but this too gradually diminishes. This diminution in the excitability of muscle is known as the *reaction of degeneration.* The paralysis of muscles may be recognized in various ways. First, by inspection and palpation of superficial muscles when appropriate movement is attempted, e.g., the deltoid, the biceps, or the adductor of the thumb. Second, by the performance of a movement for which the questionable muscle is solely responsible, e.g., flexion of the terminal phalanges of the fingers by the flexor digitorum profundus. Third, by palpation of the tendon of a muscle when an appropriate effort is made by the patient to use it, e.g., tightening of the tendon of the flexor carpi ulnaris as it attaches to the pisiform bone when wrist flexion is attempted. Fourth, diagnosis by exclusion, e.g., loss of flexion due to injury to the flexor digitorum sublimis by ruling out paralysis of the flexor profundus and the intrinsic hand muscles. Variation in muscle innervation by two adjacent nerves, such as the ulnar and median supply to forearm and hand musculature, may be studied by temporary local anesthetic blockade of the two nerve trunks differentially.

Recovery of Function. Numerous factors affect the range, degree, and character of recovery following division and suture of nerves. The principal nerves of the extremities are mixed—motor and sensory. The accuracy of suture of the divided nerve ends and the amount of scar tissue that forms between them will affect the result, as will the distance to be traversed by the regenerating axons in reaching their ultimate destination. In the regeneration of sensory nerves, the sensibility to pin prick is first regained, while that to light touch is the last to recover.

The time of return of motor function, likewise, depends upon the distance from the point of suture to the motor end plate in the muscle. The length of time that paralysis has persisted has much to do with the degree of improvement that follows suture. When it has existed for many months, the muscle atrophy, degeneration, and fibrosis become pronounced and often permanent. Since overstretched muscles lose their elasticity and contractility, they must be protected in positions of relaxation during the paralysis and pending recovery. Such factors affect the ultimate result as well as regeneration of the nerves themselves. It is unlikely that any mixed nerve ever shows complete recovery. Regenerating axons branch, sensory axons may grow along motor routes, and motor fibers find strange muscles, so that normal function is rarely restored. Such nerves as the radial, noted for favorable results after suture, have a relatively small number of sensory fibers in proportion to the motor, so fewer of them go astray. In addition, this nerve supplies muscles not highly specialized in function. The manner of action of a muscle has much to do with the apparent functional recovery. For example, a muscle which has regained only slight contractility may, by reason of an advantageous fulcrum, produce a wide though possibly weak movement. For example, slight contraction of the extensor carpi radialis may produce complete wrist extension. In contrast, a proportionate contraction of muscle fibers in the adductor of the thumb produces a movement with only a slight range and effectiveness.

Treatment. Immediate examination of motor and sensory functions of an injured extremity is always required. If impaired function is discovered, a detailed charting of sensory pattern (Fig. 2) and tabulation of motor strength by muscle are desirable. A standard motor grading is provided by the following:

0. No function
1. Flicker, either seen or felt
2. Contraction with gravity eliminated
3. Contraction against gravity
4. Contraction against mild resistance
5. Contraction against strong resistance

In the case of a clean, sharply incised wound under optimal conditions, primary nerve suture may be justified. Both ends of the nerve must be fully exposed and handled in the gentlest manner. Flush approximation of the nonrotated bundles is accomplished with sutures of fine arterial silk or steel after sharp razor excision of injured tissue. The sutures

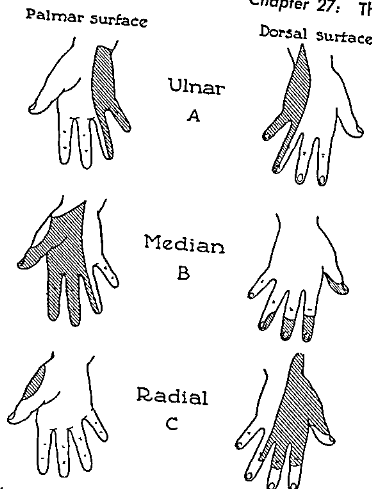


Fig. 2. Areas of hand hypoesthesia or anesthesia occurring in paralysis of nerves of the upper extremity. A, ulnar; B, median; C, radial. Due to overlap of other nerves the area of anesthesia on the dorsum of the hand following severance of the radial is usually much smaller than shown.

are placed in the epineurium only, and the line must rest with minimal tension.

In all other wounds, it is desirable to delay nerve suture until approximately three weeks following injury. At this time and for a short period thereafter, the Schwann cell proliferation is optimal for re-establishment of continuity of the tubules. There is more certain definition of the degree of injury to the nerves and consequently more accurate excision of injured nerve tissue back to succulent fibrils. The sutures hold in the thickened epineurium to better advantage and the handling of the tissue is likely to cause less additional damage. In the fresh wound, therefore, except as noted above, the nerve ends are merely noted and profitably tagged with a steel suture or possibly gently approximated by a single sling suture placed near the injured ends to retard retraction of these. Definitive neurorrhaphy is delayed until the wound is clean and healed, or until three weeks have elapsed, whichever is longer.

Secondary suture is required in wounds closed primarily without suture of the nerve and is necessary in practically all war wounds because they are not closed at the time of débridement. Numerous methods of repair of severed nerves have been suggested, and one proposed by Tarlov (1) appears to be very acceptable. The nerve ends are approximated by use of two mattress sutures of fine silk taken in the epineurium, and the suture line stabilized by fresh plasma allowed to clot around the nerve ends. Obviously, in nerve repair, great care must be exercised in prevention of rotation of one of the ends as they are approximated. Details of peripheral nerve injury may be found in the excellent monograph by Lyons and Woodhall (2).

A considerable gap between severed nerve ends may occur because of the resection nec-

essary to remove the neuroma and fibrous tissue, or from retraction of the free ends. Various methods are used to overcome the gap and permit accurate coaptation of sound tissue. Long incisions with free mobilization of the nerve, flexion of joints and favorable positioning of the extremity to shorten the distance to be bridged, and transportation of the nerve to shorter routes (viz., transposing the ulnar nerve to the front of the elbow or the radial anterior to the humerus) are the procedures which have been used. Autogenous nerve grafts have not been satisfactory in man except for the small nerves of the hand. Resection of bone to shorten the extremity and obtain approximation is infrequently justified.

The region of suture should be placed preferably in a muscle bed free from scar. The position of the extremity after operation should be such that the line of suture is not under tension. If it has been necessary to put the extremity up in flexion to accomplish this, the straightening process should be gradual and, depending upon the amount of tension, should require two to six weeks. Occasionally, the gap to be bridged may be so great as to necessitate two operations. In the first stage, a gross fastening of the nerve ends together, with the extremity in flexion, is followed by a gradual stretching and lengthening. The second stage and accurate suture may be accomplished with a repetition of the flexed position followed by gradual extension.

It should be emphasized that immobilization of joints leads to stiffness, sometimes permanent. Where splinting is required, slight flexion and extension within the permitted range is most desirable. Long, continued immobilization of joints in the presence of peripheral nerve injuries leads to irreversible joint changes.

If the axis cylinders are prevented from reaching the distal stumps because of the presence of a fibrous tissue barrier or for other reasons, the proximal stump may grow in a coiled fashion with the ultimate formation of a tumor known as a *neuroma*. If the resulting pain, tenderness, and paresthesia are sufficiently severe, the neuroma may be resected and the freshly cut ends sutured. Such tumors are also likely to form in amputation stumps and may be the cause of severe pain and local tenderness. Operative removal of the neuroma may be tried but is not always curative (see p. 620). At the flexor surface of the wrist, large sensitive neuromas are likely to follow suture and to recur if removed; cases for operation must be chosen carefully. Incomplete recovery with dysfunction may take place following injury to unsevered nerves, as well as following suture. On some occasions, a neuroma as described above is the explanation of the poor result. On other occasions the nerve becomes imbedded in callus of an adjacent fracture, or fibrous tissue is deposited to such an extent that the nerve fibers are compressed. Under such conditions, an operation (*neurolysis*) is justified. Freeing the nerve may permit resumption of part of its function. Depending upon the anatomic and physiologic condition of the nerve, actual resection with resuture may be indicated if functional loss is severe. Whereas in closed injuries with total nerve paralysis it may be justifiable to await signs of nerve regeneration, in the case of injuries with open wounds, surgical visualization of the nerve is recommended to determine its pathologic state and treat accordingly. The divided nerve requires no further comment, but the nerve in continuity may challenge the surgeon's judgment. The appearance and feel of the nerve at site of injury are important, and the response to its stimulation may guide the decision as to the correct surgical procedure—excision and suture (or resuture if a re-exploration) neurolysis, transposition to a better environment, or further observation.

The management of the patient with an injured nerve requires care to the skin and joints of the part and appropriate flexible splinting to support paralyzed or recovering muscles, at the same time permitting therapeutic and prophylactic motion; also important is the daily employment of massage and, when possible, galvanic stimulation to the paralyzed muscles to reduce the ravages of combined atrophy and fibrosis. When nerve dysfunction develops following trauma, early neurolysis is indicated to avoid nerve degeneration, muscle atrophy, and the like. (See Lesions with Incomplete Paralysis, p. 620.)

Injury to Special Nerves. Lack of space prohibits discussion of the clinical findings characteristic of all the various nerves which may be injured. There are a few (ulnar,

radial, and median), however, which are injured so frequently as to justify individual discussion. The ulnar and median nerves are readily severed or injured by lacerations of the forearm, which are so commonly sustained in both industrial and automobile accidents. Obviously, the findings will vary somewhat, depending upon the level at which the nerve is injured. Details of nerve injuries in the hand will be found in Chapter 17; however, some of the fundamental points are included below.

The *ulnar nerve* is injured most commonly by incised wounds of the forearm and wrist, penetrating wounds of the palm, and by fractures which involve the medial condyle of the humerus. The area of sensory impairment in complete division of the ulnar nerve includes the fifth finger, the neighboring half of the ring finger and the corresponding portions of the palmar and dorsal surfaces of the hand to the wrist (see Fig. 3). The only area, however, from which *all* forms of sensation are lost is the terminal phalanx of the little finger. Complete sensory loss of the terminal phalanx, therefore, is proof of complete ulnar interruption. Several types of motor disability are also produced, depending on the level of injury. Since the ulnar nerve supplies many of the intrinsic muscles of the hand (see *median*), division of this nerve results in considerable motor disability for finger movement of the hand (Fig. 3). Because of paralysis of the interossei muscles, there is a weakness of the power of flexion at the metacarpal phalangeal joints, especially of the ulnar side of the hand. Abduction and adduction of the fingers are impossible because of paralysis of the dorsal and palmar interossei, although other muscles can perform this function to a slight degree. Paralysis of the interossei also prevents extension of the tips of the fingers, particularly when the metacarpophalangeal joints are bent at a right angle. Paralysis of the adductor pollicis muscle prevents the patient from bringing his thumb against and in front of the base of the index finger. The patient is also unable to approximate the tips of the fingers. If the nerve is injured at the elbow, as frequently occurs at the groove of the internal condyle of the humerus, there will also be a weakness of the long flexors of the fourth and fifth fingers and the flexor carpi ulnaris.

As time elapses and the intrinsic muscles atrophy, a flexion deformity of the fingers (most marked on the fourth and fifth fingers)

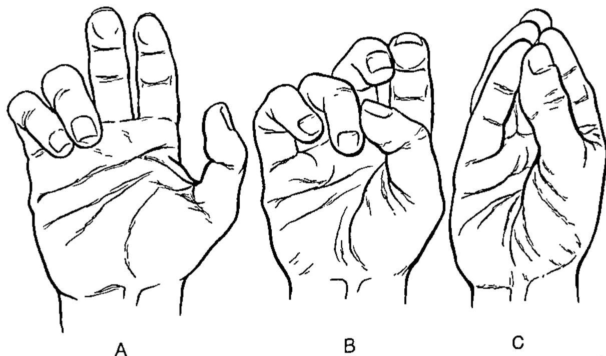


Fig. 3. Motor findings in ulnar nerve paralysis. A, clawing of inner two fingers; B, inability to oppose all finger tips as compared to the normal in C. (See also Fig. 12, Chapter 17.)

known as the "claw hand" (main en griffe), is produced. This deformity is produced chiefly because of paralysis of the interosseous muscles. Since the power of flexion of the fingers at the metacarpophalangeal joints, and extension of the second and third phalanx, is controlled by the interossei, their paralysis will allow the opposing muscles to draw the fingers into flexion with extension at the metacarpophalangeal joint. This deformity is similar to but actually quite different from that observed in Volkmann's contracture (p. 556) and other lesions. Restoration of function following suture of the ulnar nerve is unusually slow and incomplete. The first function to be regained is sensibility to pin prick. Function of the intrinsic muscles returns only after a year or two (depending somewhat upon the level of injury), but is rarely complete. After two years further restoration is unlikely.

The *median nerve* is often severed by deep lacerations above the wrist. It supplies the abductor and opponens pollicis, two outer lumbricales, and the deep head of the flexor pollicis brevis muscle of the hand. Paralysis of the opponens pollicis muscle, which is one of the most diagnostic features of injury to the median nerve, prevents rocking of the thumb, so that apposition of the tip of the thumb to the base of the little finger is impossible. Abduction of the thumb, which is performed by the abductor pollicis, is inefficient if the median nerve is severed (Fig. 4). If the nerve is injured at or above the elbow, flexion of the distal phalanx of the thumb and of the index finger is impossible because of paralysis of the flexor muscles to those digits. The sensory disturbance accompanying injury to the median nerve is the same regardless of the level of injury above the wrist; i.e., the radial side of the palm and tips of the index, middle, and ring fingers (see Fig. 3). The terminal phalanx of the index finger is the only part that is totally anesthetic in complete median lesions. Recovery of sensation is of the greatest im-

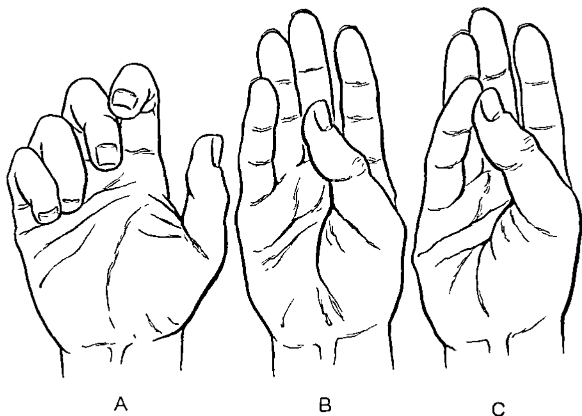


Fig. 4. Motor findings in median nerve paralysis (injury in upper forearm). A, inability to make a fist; B, inability to oppose the thumb to the little finger compared to the normal in C. (See also Fig. 9, Chapter 17.)

portance in the median nerve supply. Permanent loss of sensation in the index finger and thumb involves great disability, therefore sensory restoration in this nerve is more important than motor improvement.

The *radial (musculospiral) nerve* lies in direct contact with the humerus, winding around just below the insertion of the deltoid. It is, therefore, frequently injured, especially by fracture or by compression in the callus accompanying the healing of fractures of the middle third of this bone. Postoperative paralyses are occasionally encountered due to pressure by allowing the patient's arm to hang over the side of the table during an operation. If such pressure exists for a short time only, the paralysis is usually transient. The motor disturbance created by injury to the radial nerve is confined chiefly to the extensors of the wrist, fingers, and thumb, and produces the disability commonly known as "wrist drop." (See Ch. 17, Fig. 8.) If the nerve is injured high in the axilla, paralysis of the triceps may also occur, resulting in inability to extend the forearm. The sensory areas involved are located on the radial side of the dorsum of the hand and the radial side of the wrist.

Regeneration of the radial nerve after operative repair of the injury is fairly satisfactory and, in general, is better than that after repair of the median or ulnar nerve. Prognosis as to restoration of the power of extension of the wrist and fingers is usually favorable. It is important that wrist drop be prevented by supporting the hand in a dorsiflexed position in an elastic splint which does not immobilize the joints.

Lesions with Incomplete Paralysis. Under this heading will be considered various types of nerve lesions many of which may be classified as *neuritis;* some are presumably caused by toxins or chemicals and others by *trauma.* The important feature, however, is that the disturbance is only partial, and if the causative factor can be found and eliminated, complete recovery usually can be expected. Such lesions may present either sensory or motor manifestations or both. The most frequent of this type of neuritis is produced by *pressure* or *mechanical irritation* of a nerve, and manifests itself by pain, paresthesia, tingling, numbness, hyperesthesia, paresis, and the like, in the region of the nerve and its distribution. Stretching of the peroneal and ulnar nerves during manipulation for the correction of deformities are examples. Other examples are: injury to the peroneal nerve just below the head of the fibula by a plaster cast, injury to the ulnar nerve accompanying fixation of a fractured elbow put up in flexion, and paralysis of the median nerve from kinking at the annular ligament when a swollen wrist and hand is put up in flexion. The pathologic changes in and about the nerve are variable and depend upon the type of injury. They may vary from demyelinization to hemorrhage and crushing of a small amount of tissue, followed by deposition of scar tissue in and adjacent to the nerve. Early operation is advisable in injuries of this type because of the muscle atrophy, stiffness of joints, and nerve degeneration which might result from prolonged nonoperative therapy. Operation should be performed within a month following injury if no improvement is noted by that time, or if partial involvement progresses. Operation consists of removal of constricting bands of scar tissue about the nerve, neurolysis (i.e., lysis of the thickened sheath), and transfer of the nerve to a new position out of its bed of scar tissue if possible. On some occasions, removal of the cause may be followed by rapid amelioration of symptoms. On other occasions, contusion of the nerve may be so severe as to produce paralysis (sensory or motor) until regeneration takes place. Since the nerve itself is usually not severed, regeneration takes place after removal of the cause unless sufficient scar has been deposited actually to interfere with the growth of the axon down the sheath. If motor paralysis remains after removal of the cause, protective measures, such as splinting of the part to prevent contracture due to an overpull by the antagonistic muscles, must be instituted. All such splints must be removed several times daily, and joints manipulated by active motion to prevent stiffening.

Transplantation of the ulnar nerve to the antebrachium is often remedial to the condition of tardy ulnar paresis occurring following injuries about the olecranon groove. Occupational hazards may cause recurring mild injury leading to fibrosis about this same nerve in its vulnerable position, and produce

incomplete lesions which may be benefited by transposition. Compression of the median nerve *in the flexor carpal canal is another* example of the role of joint injury or arthritis or recurrent minor traumata in producing a painful or weak extremity. Section of the flexor retinaculum with release of the nerve is often helpful.

Another group of incomplete nerve damage syndromes is due to a *toxin* or *chemical poison*, e.g., lead, alcohol, and arsenic poisoning affecting also other parts of the body. The symptoms reduced by this type of neuritis, which is frequently designated as polyneuritis, consist of paresthesia and various motor nerve paralyses, especially wrist drop. Important surgically is the use of supports and appliances to prevent contractures.

Cervical ribs have a surgical interest because they may produce neurological as well as circulatory changes. This congenital anomaly is almost always confined to the seventh cervical vertebra; the ribs vary considerably as to their stage of development. Very *few are sufficiently developed* as to be attached to the manubrium. More commonly the rib is short; it may or may not terminate in a fibrous band which is attached to the first rib near the scalene tubercle. Most cervical ribs are found accidentally in x-ray films and do not produce symptoms. When symptoms are produced, the most common manifestation is numbness and tingling of the hand in the distribution of the ulnar nerve. The fibers of this nerve are contained in the lower cord of the plexus and are, therefore, most susceptible to pressure by the cervical rib (Fig. 5). However, other fibers may be involved. Actual weakness of muscles of the hand or flexors of the wrist may be present. Less often there may be evidence of compression or spasm of the subclavian artery as exhibited by coldness and cyanosis of the fingers and decrease in volume of the radial pulse, par-

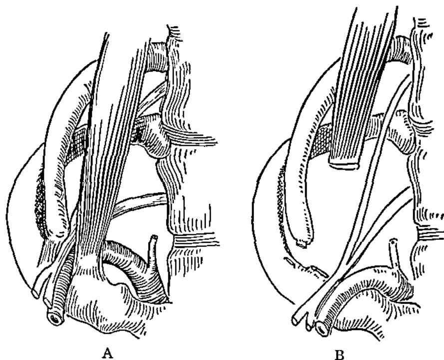


Fig. 5. The mechanism by which cervical ribs may produce unilateral disorders of nerves and blood vessels (scalenus anticus syndrome). Cervical ribs may compress the nerve trunks constituting the brachial plexus and produce a type of traumatic neuritis. They may likewise diminish the volume of the radial pulse, with decreased blood pressure on the side or sides affected. A, the end of the cervical rib or its fibrous attachment (when present) to the first rib may compress the subclavian artery and nerve trunks against the scalenus anticus muscle; B, section of the scalenus anticus near its attachment to the rib allows the artery and nerve trunks to slide medially and downward, thereby eliminating the pressure on them.

ticularly when the arm is held in a dependent position with the shoulder relaxed. On rare occasions, superficial areas of gangrene will develop on the fingers.

The *treatment* of symptoms produced by cervical ribs is satisfactory and consists of release of the pressure upon the artery and nerve trunks. Although this may be accomplished best by removal of the larger ribs, it will not be necessary when the rib is very short or terminates in a fibrous cord. In most instances, the artery and nerve trunks are compressed between the scalenus anticus muscle and the cervical rib or its fibrous attachment. Section of this muscle at its insertion without removal of the cervical rib will allow the artery and nerve trunk to slide forward with subsidence of symptoms.

The symptoms of *brachial plexus neuritis* first described by Murphy (3) and Naffziger (4), are similar to those produced by cervical rib, but occurs in absence of a cervical rib. The term *scalenus anticus (Naffziger) syndrome* (Ochsner and associates, 5) seems to be an appropriate designation, because section of the scalenus anticus muscle is usually curative. Other mechanisms may produce symptoms and findings similar to those of the rib and muscle complex just described. The cords of the brachial plexus may be compressed by normally occurring structures such as the first rib, a pectoralis minor muscle, or the subclavius muscle. It may be involved by a superior sulcus tumor or an aneurysm of the subclavian artery. The most common error in diagnosing the cause of upper extremity pain is lack of recognition of the importance of cervical root compression by intervertebral disk disease.

Causalgia is characterized by severe burning pain, occurring at intervals up to several weeks following injury but usually appearing within 24 hours of injury (6). The syndrome occurs in mixed sensory motor nerves in which the sensory component is prominent, and in most every instance the lesion of the nerve is incomplete. Weir Mitchell, who originally described the condition, noted it was observed most commonly following war wounds. The pain occurs in attacks and is commonly revived by a touch or slight jar to the affected extremity; paresthesia is fairly constant. At times the discomfort is severe, demanding specific therapy. Bone atrophy in the affected extremity is common; at times it may become severe and may be responsible for symptoms, particularly pain. Any sensory stimulation (sound, light, and so forth) aggravates the pain. Emotional and psychic stimuli aggravate the pain. The patient with hysteria shows no vasomotor changes except those due to immobility. Sympathectomy is usually effective. Early diagnosis and immediate treatment save much suffering and eliminate permanent disability.

Involvement of segmental peripheral nerves of the trunk in operative incisions upon the thorax and abdomen may produce disagreeable and, at times, incapacitating neuritis. It is most frequently encountered in thoracotomy and herniorrhaphy incisions. Revision of the painful scar and nerve section rarely stops the pain, particularly after the pain pattern has become well established. Local nerve block may be tried, but alcohol used too near the spinal canal may spread proximally into the subarachnoid space and should be used with great caution. Infrequently the condition may call for posterior root section of several segments or tractotomy. The best treatment is prevention.

Hiccup (*Singultus*) is a common complaint, produced by a sudden spasm of the diaphragm associated with the closure of the glottis, and has been classified, though perhaps incorrectly, as a type of neuritis. The abnormal impulse is transmitted by the phrenic nerve. In its most frequent form it is apparently of reflex origin from disorders of the stomach or intestine. It is commonly encountered as a complication of abdominal operations; in other instances it is instigated perhaps by irritation or inflammation of the diaphragm as produced by peritonitis, mild or severe. Occasionally the condition is caused by intracranial tumors but in such instances, is not severe. Various methods of treatment are available but not specific. Sedation, gastric lavage, inhalation of carbon dioxide, rebreathing into a paper bag, and many other remedies may be helpful. Friedgood and Ripstein (7) report good results in 80 to 90 per cent of patients treated with chlorpromazine. They used a dose of 50 mg. intravenously but reduced the dose to 25 mg. in elderly patients. When the above conserva-

tive measures fail and the condition is proving to be an exhaustive complication, the phrenic nerve may be blockaded or isolated by operative procedures and the impulses broken by various means. In most cases, however, in the absence of serious disease such as peritonitis or uremia, the hiccup even after days or weeks of unsuccessful therapy will disappear as quickly as it came.

Herpes Zoster (Shingles). This condition is caused by a neurotropic virus located in the cranial or spinal ganglia and posterior roots. The ganglia associated with the fifth cranial nerve and the intercostal nerves are most commonly affected. Severe pain, which is usually of a constant debilitating character, radiates along the course of these nerves. The skin over the area supplied by the nerves becomes red and edematous and vesicles soon appear. Such vesicles may become secondarily infected. In the severe cases, the pain is intense. The disease occurs, however, in all variations of severity and frequently is so mild or of such short duration as not to demand special treatment. Since pain precedes the herpes, which in some cases may be absent, the disease may be mistaken for other lesions, particularly acute intraabdominal disease.

TREATMENT. In the acute phase of vesicular eruption, irradiation of the spinal segment involved, paravertebral sympathetic blockage (8, 9, 10), and various systemic medications have unpredictable results. The pain frequently is self-limited but in a minority of patients severe posthepatic neuralgia persists and is disabling. In the treatment of this chronic form of posthepatic neuralgia, local nerve blocks or resections may have temporary benefit. Dorsal root section is useful in a further group, and, in severe intractable spinal cases, spinothalamic cordotomy may be recommended with relief in about 50 per cent of cases. Prefrontal lobotomy is required rarely. The operative procedure of peripheral elevation of pedicled flaps in the area of the diseased skin and denervation of such flaps with or without grafting holds promise.

The Cranial Nerves. The *first* or *olfactory* nerve carries impulses responsible for the sense of smell, and by this means likewise contributes to a great extent to the sense of taste. Its chief surgical significance lies in the fact that loss of the sense of smell aids in the localization of brain tumors and the site of brain damage in head injuries, particularly those accompanying fracture of the anterior cranial fossa.

The *second* or *optic* nerve, transmitting stimuli which give rise to the sense of sight and the light reflex, is one of the most important of the cranial nerves. Lesions affecting one or both optic nerves or visual pathways produce defects in the visual fields which are commonly due to a surgically important lesion. Papilledema, which is a swelling of the nerve trunk ending in the retina, is secondary usually to an increased intracranial pressure of subacute or chronic nature. This condition may be brought about by a number of causes, including brain tumor, brain abscess, intracranial injury, encapsulated blood or fluid, or blockage of cerebrospinal fluid flow. If the intracranial pressure is allowed to persist, the papilledema passes into the stage of "secondary atrophy" with impairment of vision or permanent blindness.

The *third* (*oculomotor*), *fourth* (*trochlear*), and *sixth* (*abducens*) nerves innervate the external muscles of the eye. Inflammatory or neoplastic lesions of the brain or fractures of the base of the skull may create a disturbance in the normal movements of the eyeball by injury to these nerves. A carotid aneurysm is a frequent cause of oculomotor paralysis and is to be particularly suspected if the onset of the paralysis is sudden. Careful examination of the movements of the eye is obviously important in detecting intracranial lesions of various types. Malignant tumors arising in the nasopharynx frequently invade the base of the skull and cause paralysis of isolated nerves or nerves in combination, the most common being the sixth cranial nerve and the fifth cranial nerve.

The *fifth* (*trigeminal*) nerve is rarely injured, but is frequently the seat of a neuralgia which is known as *tic douloureux*. Involvement of the trigeminal nerve from whatever cause if combined with a facial paralysis requires prompt tarsorrhaphy to protect the cornea from ulceration.

Trigeminal neuralgia (tic douloureux) produces severe, excruciating paroxysms of pain distributed along one or more of the divisions of the nerve (usually the second and third).

The onset is abrupt, with severe pain radiating to the upper or lower jaw. If the second division is involved, the pain will be confined chiefly to the cheek and upper lip. Although the disease usually affects one division at first, there is a tendency in time for all three to become affected. There are no objective sensory changes in the skin over the area of the face affected, but there is a peculiar reflex sensitivity insofar as a slight touch may at times set off a paroxysm which characteristically is located in the upper jaw but may extend to the mandible and nose (trigger zones). In character it is sharp, lightninglike, stabbing, or electric in quality. One shock may succeed another over a few seconds, the offset of the pain is as abrupt as the onset. In the intervals there may be no pain whatever, though at times there is a more or less persistent discomfort. Remissions of weeks or months characterize the disease. The average age of the sufferers is between fifty and sixty. In the very young there may be an association with other nervous diseases, such as disseminated sclerosis or a tumor in the cerebellopontine angle or gasserian ganglion. The pain is usually severe enough to require sedation, although such narcotics as morphine should be avoided because of the danger of drug addiction. Permanent cure is produced by section of the sensory root of the fifth nerve, either in whole or in part. The motor division can be spared. The anesthesia is permanent. If the pain does not involve the first division, that portion of the root should not be sacrificed, as permanent anesthesia of the cornea involves obvious dangers.

It may be wise first to inject the involved branch with alcohol. This is usually effective in relieving the pain for several months. It may be repeated, or avulsion of the root be performed by operation. Alcohol injection may be a useful therapeutic test for what may be accomplished permanently by operation. It also acquaints the patient with the numbness he will have after nerve root section. Trichloroethylene inhalations are effective in alleviating the attacks in a minority of cases.

The etiology of trigeminal neuralgia is unknown. There are no objective neurological findings. It is unaffected by the removal of teeth or surgical attack on the sinuses. It tends to become worse. Decompression of the sensory root and internal neurolysis of its fibers in its dural canal over the apex of the petrous bone (Taarnhøj, 49) may produce relief without sensory loss. Division of the sensory root gives permanent cure and in skilled hands carries a mortality of less than 1 per cent.

It is important to distinguish between major trigeminal neuralgia (tic douloureux) and the atypical neuralgias of the face which arise in other pain-sensitive structures about the neck, face, and cranium and for which fifth nerve section is decidedly not the correct treatment. Migrainous hemicrania of vascular origin, pain from disease or malocclusion of the temperomandibular joint (Costen's syndrome), pain from dental and cervical disease, and pain of muscle spasm and tension are examples in point.

The *seventh (facial)* nerve, which is primarily a motor nerve supplying the muscles of the face, is occasionally injured by operative procedures, fractures of the base of the skull, infection about the middle ear, and mastoid operations. Paralysis of the facial nerve results in a disfiguring deformity due to the unilateral loss of facial expression and shifting of the mouth toward the unaffected side (Fig. 6). Since the nerve divides into its branches in the outer surface of the parotid gland, operations in this area may result in injury to the nerve. Spontaneous, though often transient, facial paralysis also occurs without evidence of any other disease or as the result of various infections, viruses, and toxins (Bell's palsy). These seventh nerve paralyses are of the peripheral type, characterized by inability to close the eyes or wrinkle the forehead. In contrast to this are the lesions which are of supranuclear origin, in which only the lower facial muscles are affected. Thus the patient retains the ability to close the eye and wrinkle the forehead.

In permanent facial paralysis of the peripheral type, the facial deformity may be corrected to a great extent by a plastic operation, which includes the transplantation of facial strips, anchored subcutaneously in order to hold up the paralyzed face, particularly the side of the mouth. In peripheral facial palsy where there is some possibility of recovery, the facial muscles should be supported and

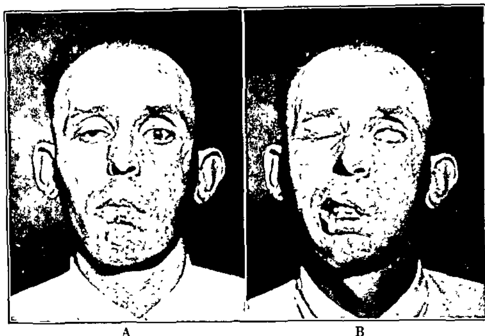


Fig. 6. Paralysis of the seventh nerve produced by a gunshot wound of the face. A, with the facial muscles at rest the only evidence of paralysis (in this instance) is a slight deviation of the mouth toward the unaffected (right) side, and a lack of wrinkles on the paralyzed (left) side; B, when the patient is instructed to close his eyes and "show his teeth," a marked distortion results because of the paralysis of muscles on the left side.

kept relaxed to prevent overstretching. Manual massage inside and outside the cheek will aid in accomplishing this. Adhesive straps attached to a band about the head may be used.

For permanent, complete injuries of the facial nerve proximal to the stylomastoid foramen, a hypoglossal-facial anastomosis performed in the neck is the treatment of choice. Discrete facial motions do not return but facial tone and gross movements do, and provide a more acceptable cosmetic result. Spasmodic facial spasm is usually of psychogenic origin, but in certain cases of nuclear facial spasm of presumed organic origin, partial peripheral fiber section is advantageous. Electromyographic study of the facial muscles is helpful in distinguishing the two.

The *eighth* (*acoustic*) nerve is occasionally injured in fractures of the skull, but more commonly the equilibratory sensation is impaired by cerebellar lesions (tumor). The nerve itself may be the seat of neoplastic growths, *e.g.*, acoustic neurinoma or von Recklinghausen's disease. Ménière's disease, which is characterized by severe vertigo, nausea, vomiting, and unilateral tinnitus in an ear which is partially deaf, is treated successfully by the intracranial section of the eighth (auditory) nerve or of its vestibular portion. Streptomycin may lead to eighth nerve involvement when given to susceptible patients as chemotherapy. A form of "toxic" labyrinthitis associated with respiratory infections often leads to temporary dizziness from intense stimulation of this nerve.

The *ninth* (*glossopharyngeal*) nerve is of surgical significance because of the occurrence of *glossopharyngeal neuralgia*, which is similar to trigeminal neuralgia except that it is more rare and is confined to the anatomic distribution of this nerve. The act of swallowing is usually most painful and the tonsillar fossa is the "trigger point" which initiates the pain. Local anesthetization of the tonsillar fossa may be helpful in stopping the pain and aiding in diagnosis. Pain in the ear often accompanies the paroxysm. *Treatment* consists of the intracranial section of the ninth nerve. Occasionally, intracranial lesions (tumors, and so forth) compress the fibers constituting this nerve and produce an impairment in taste and deglutition. By receiving the carotid sinus

nerve of Hering, the ninth nerve is the important afferent limb of the carotid sinus reflex and is of importance in transmitting impulses which may produce asystole and syncope from excessive vagal influence—the carotid sinus syndrome—mediated by the tenth nerve (see below).

The *tenth* (*vagus*) nerve is of special significance since section or destruction of both nerves in the cervical region is fatal to man. It contains fibers which carry autonomic impulses of the parasympathetic type to and from the abdominal and thoracic organs. Occasionally, tumors compress the vagus in such a manner as to create an irregularity in the cardiac rhythm. Because of its position in the posterior portion of the carotid sheath, it has no doubt been mistaken for the phrenic nerve or sympathetic trunk and occasionally removed. Its peripheral branches below the diaphragm have been divided in the treatment of peptic ulcer (see p. 735). Injury to the recurrent laryngeal branch of this nerve in cervical surgical procedures and involvement of the nerve in cervical malignant tumors are well recognized.

The *eleventh* (*spinal accessory*) nerve supplies the sternomastoid and trapezius muscles and may readily be injured or severed during operations upon the lower part of the neck, such as dissection for carcinoma, or removal of lymph nodes in the posterior triangle of the neck. The degree of disability and discomfort following such paralysis is variable; at times it is extreme.

The *twelfth* (*hypoglossal*) nerve which supplies the muscles of the tongue should be avoided in block dissection beneath the jaw for carcinoma. Severence of one hypoglossal nerve results in unilateral atrophy of the tongue with deviation to the side of the injury. Disturbances in deglutition and articulation are not marked, so that this nerve is often severed and crossed with the facial nerve in instances of permanent facial palsy.

THE BRAIN

Craniocerebral Injuries. The term *head injury* is often used to include three groups of trauma, which occur so frequently together that they are described here in the section on brain: 1. injury to the scalp; 2. fracture of the skull; and 3. intracranial injury. This classification will be used in the following discussion, except that most of the space will be devoted to varieties of intracranial injuries which, it should be emphasized, represent the most important of the three groups, being responsible for the serious and often fatal results. In the following discussion, a distinction must be kept in mind between the closed head injury on the one hand and the open, compound, or penetrating wound on the other. The mechanism of injury varies with each and clearly the surgical pathology is different.

1. *Injury to the Scalp*. In any patient with such an injury it is obviously important to know whether or not a skull fracture and intracranial injury are present. A history of the mechanism of trauma and of the presence or absence of impaired consciousness immediately following injury is of importance. Examination of the head may reveal contusions, hematomas, or ecchymotic patches anywhere about the scalp. The presence of a laceration of the scalp is of extreme importance because of the possibility of detecting an underlying fracture which may demand repair, as will be discussed later. Local tenderness may be elicited even if the patient is only partially conscious. Clipping of the patient's hair may be required to discover signs of scalp injury which may constitute important evidence of the role of injury in explaining a clinical picture of impaired consciousness.

Edema of the scalp extends along linear fractures. Presence of pitting and tenderness may permit the diagnosis of linear fissures. A scalp hematoma with a soft crater may sometimes simulate a depression in the skull though continued pressure on its margins may alter it and indicate its character; frequently, differential diagnosis between it and a depressed fracture may be possible only by x-ray. Aside from the opportunity to estimate damage to the underlying bone and brain, a simple scalp injury presents no other feature of importance. It needs emphasis, however, that extensive scalp lacerations may be associated with important blood loss and shock. The treatment of this uncomplicated lesion has been described under Wounds; such injuries will heal readily if clean, because of ample blood supply. Careful separation of the wound edges, inspection and cleansing are commonly neglected. In World War II this

resulted in so many serious infections of scalp and bone that in England scalp lacerations were listed as reportable to the area consultant. Wide shaving of the surrounding scalp, thorough cleansing and removal of avascular contused and ragged scalp edges, inspection and palpation for underlying fissure fracture lines or other evidence of bone injury, are first principles to be followed. Suture without tension with nonabsorbable silk or steel wire utilizing a buried galeal layer or figure-of-eight single layer suture which includes the galea is recommended. Antitetanic serum or tetanus toxoid (if the patient has been previously immunized) should be given, as discussed elsewhere.

2. *Skull Fracture.* Fracture of the skull rarely occurs alone; injury to the underlying brain is often associated, and injury to the overlying scalp is frequently present. Fracture can occur without brain injury, such as the eggshell fracture of a vise-type mechanism; it often dissipates the force and spares the brain of further injury. Its presence indicates the mechanism and degree of severity of the force applied but not necessarily the amount of brain injury. The serious and often fatal effects of skull fracture are *due to injury of the brain or a blood vessel, and not to the fracture itself*, except in basal fractures when meningitis may develop, regardless of the presence or absence of brain injury. When the compressing force acts from pole to pole the fracture is apt to be linear. If the head is struck a direct blow with a small object, a stellate fracture, with lines radiating outward from a central point, is apt to be produced. Such a blow, if severe enough, will result in a depressed fracture. An important example of the indirect localized depressed type is a fracture of the base of the skull sustained when the patient falls to the ground from a height, and lands on his feet or buttocks so that the impact of the heavy head strikes against the vertebral column and literally caves in the base of the skull. Such injuries are serious and usually fatal, because of the damage to the adjacent vital medullary centers. Because of the thinness of the bone in certain parts of the base of the skull, fractures in this region are particularly common. Bullet wounds produce a variable amount of shattering, depending on the speed of the missile and other factors. Because of the arrangement of the two concentric tables of the skull, a blow to the outer table may produce an innocent linear or stellate fracture line in the thin outer table but be associated with a serious fragmentation of the inner table with possible underlying soft-tissue laceration.

Fractures of the skull may be classified in many different ways. From the standpoint of the mechanism of production they may be bursting, indented, or expansile; according to the character of the fracture itself, they may be linear, stellate, comminuted, depressed, or penetrating.

Diagnosis of fracture of the skull may be made occasionally by simple clinical observations. The fracture may sometimes be palpated when depression and comminution are present; it may be seen and felt occasionally through a laceration; local tenderness is usually present over the fracture. Bleeding from the nose or ear is indicative of skull fracture if direct injury of the soft tissue can be excluded as the source of the hemorrhage. Escape of cerebrospinal fluid through a scalp wound, or from the nose or ear is pathognomonic of cranial fracture.

The diagnosis of skull fracture may require x-ray films taken in several views and often stereoscopically. From the therapeutic standpoint, x-ray is necessary insofar as it may reveal a depressed fracture which might otherwise be undemonstrable and which may require correction, or to visualize air which may enter via fractures into the sinuses. Views taken with the ray tangential to depressions are necessary to show their depth. In the case of open, compound, or penetrating wounds operative management is of course mandatory, and good quality films are required for intelligent handling. In the restless or comatose patient, it may be necessary to induce anesthesia and to guarantee an adequate airway to obtain films before taking the patient to the operating room. In the case of the closed head injury, however, x-rays will add little to the initial management of the patient except as mentioned with respect to depressed fractures; their taking is best deferred until full examination has guaranteed that the patient's condition is sufficiently stable to withstand the handling attendant upon the roentgenologic study. X-rays are recom-

mended in all cases of craniocerebral trauma.

Treatment of skull fractures is that of the associated intracranial and scalp injuries. It is directed toward minimizing the damage done by penetrating objects, to prevent infection, and for the removal of gross clots.

In the absence of demonstrable intracranial injury, ambulation is encouraged two or three days after injury (11) to minimize post-traumatic headaches. Brain damage is often present although not evident clinically. When the fracture is depressed or compound, operation is indicated. Since treatment of fractures of the skull is directed toward the brain injury, it is discussed under the various types of intracranial injury.

Depressed fractures are important because of the association with brain injury. This may be only local or it may be associated with so much widespread damage that any of the manifestations described on page 630 may be produced. Naffziger and Glaser (12) have shown that the changes in the brain are caused by the force producing the injury rather than continuing depression of the bone. However, depressions in excess of the width of the tables of the skull should be elevated. With depressed compound fractures, the problem is the prevention of infection and the removal of devitalized material to minimize gliosis and scar contraction, which may lead later to convulsions.

The skin may or may not be broken over the site of injury. An x-ray should always be taken, since a hematoma in the scalp may simulate a depressed fracture. An early neurologic examination is essential, particularly noting the eye signs and evidences of a hemiplegia. Detailed neurological examination is usually difficult because of the inability of the patient to cooperate. The reflexes should be recorded together with continued observation of voluntary movements of the extremities. Decreasing movements of one side of the body often precede actual paralysis or altered reflexes. Nurses should be instructed to make this observation. Findings carefully recorded permit comparison with later examinations and changes serve to distinguish between signs of primary damage and those which appear later due to hemorrhage.

Simple (presumably nonpenetrating) depressed fractures (Fig. 7) with an intact scalp should be elevated soon, but as an elective procedure except when progressive signs, as from hemorrhage, make operation imperative or when focal neurologic deficit corresponding to the site of injury indicates a "coup" injury with a possible subcortical clot.



Fig. 7. Depressed skull fracture. Closed, comminuted, depressed skull fracture of the frontotemporal area with laceration of meninges and cortex. Most depressed fractures, even though they be closed injuries, should be elevated if they are displaced the width of the skull or more. In the closed injury, such treatment may be delayed a day or two, unless focal neurologic deficit exists, in which case treatment should be emergent as it must be in the case of compound depressed fractures.

The most appropriate time for operative closure of open penetrating wounds is based on the general condition of the patient, the previous treatment of contamination and the presence or likelihood of infection. Débridement of devitalized tissue, including the brain, and dural repair scalp closure in general should be performed as early as possible.

Open (compound) fractures associated with in-driven bone fragments and penetrating wounds due to missiles are treated along similar lines and as early as suitable personnel and facilities are available.

It is the aim to prevent infection and minimize the damage done. Devitalized scalp margins are excised. Depressed areas may be removed en bloc or the opening enlarged and bone fragments removed piecemeal. Retention of contaminated bone fragments commonly leads to late abscess. Metal fragments, if accessible, are also removed, but widely separated fragments may be left justifiably if removal requires extensive excision of nontraumatized tissue. Devitalized brain is irrigated and sucked out so as to lessen the nidus for infection and minimize the amount of later scar. The entire tract of a penetrating wound must be cleansed back to normal bleeding tissue, but the principle of "block excision" of a contaminated wound, when applied to the brain, may cause too much sacrifice of functionally vital tissue. Watertight dural closure is a first principle. Scalp closure without tension may require extensive undermining beneath the galea and is a first requisite. Systemically administered antibiotics may decrease the risk of infection.

3. *Intracranial Injury With or Without Fracture.* Many fatal brain injuries occur without fracture of the skull. Rapid acceleration or deceleration of the head alone produces varying degrees of contusion and laceration of the brain. With generalized brain injuries the under surfaces of the frontal lobes and the tips of the temporal lobes, especially on the opposite side from the point of impact, are most prone to show damage. Focal neurological signs may not be present. If they appear later a clot is the probable cause. Bloody spinal fluid signifies brain laceration.

The simplest manifestation of intracranial injury is transient unconsciousness sustained immediately after the accident, followed later perhaps by dizziness, headache, or visual disturbances which clear up within a few hours without producing any permanent effect. This type of manifestation is often called *concussion,* a physiopathologic state due to microscopic or perhaps only functional trauma to the brain cells and reversible chemical and electrical alterations. Of considerable interest is the fact that repeated episodes of this type may lead to permanent brain damage which is observed in boxers who are said to be "punch drunk." Organic injury, consisting chiefly of minute hemorrhages particularly in the pons, is responsible for this condition. In the severe cases, the mental disturbances may develop into almost complete imbecility.

More obvious manifestations of intracranial injury consist of a great variety of specific signs and symptoms sometimes masked by the effects of coexistent acute alcoholism. Moreover, they may vary greatly from hour to hour in the same patient which emphasizes the importance of frequent observation. Many of them have already been discussed to a certain extent in Chapter 16 and include surgical shock, abnormalities in respiration, manifestations of increased intracranial pressure, and various types of sensorial changes from coma to hyperactivity; other evidences comprise those more local in character, such as cranial nerve paralyses and leakage of cerebrospinal fluid from wounds, ear, or nose. So important are these various types that they are discussed in some detail. Treatment is also described under each variety of injury. In the civilian automobile injury of today it is well to remember that when a patient is hurt he is often hurt all over and the responsible surgeon must be alert to injury to all parts of the body.

There are *several varieties of intracranial injury* consisting of contusion and laceration of brain tissue, of hemorrhage, edema, and compression, and of actual destruction or loss of brain tissue. The hemorrhage may be massive and local, or diffuse and petechial in type; it may be within the brain, subdural, or extradural. The contusion or laceration of brain tissue may be diffuse or localized; cerebrospinal fluid may escape subdurally (extra arachnoid), where it is absorbed slowly thus increasing intracranial pressure, or it may leak externally when a compound fracture exists. Most of these various lesions may be differentiated clinically. Often a combination of two or more will be present, thus complicating differential diagnosis. Nevertheless, the therapy may be so different in each type that the surgeon should seriously attempt to determine the type and severity of the injury and particularly its development by frequent observation. In the following classification, *four types of injury are discussed:* 1. diffuse injury with edema; 2. extradural hemorrhage; 3. subdural hemorrhage; and 4. intracerebral



Fig. 8. Fatal cerebral contusion. Severe craniocerebral injury with cerebral contusion associated with temperoparietal fracture. Note the widespread subarachnoid blood and massive swelling of the hemisphere with displacement and distortion of the ventricles and other midline structures.

hemorrhage. The treatment indicated will be described in each type.

1. *Diffuse Injury.* This group represents the most serious type of injury and is frequently fatal. Contusions and lacerations may be extensive throughout the brain. A variable amount of tiny and massive hemorrhages within the brain or along the meningeal surfaces is associated with the injury. The contusions and lacerations are responsible for the development of edema which, with hemorrhage, may readily produce serious manifestations purely from increased pressure (Fig. 8).

A variable degree and duration of *unconsciousness* will be present, dependent upon the severity of the injury. In many instances, vertigo and headache will be fairly constant complaints. Nausea and vomiting may be present. In the more severe cases the skin is usually pale and the extremities are cold and moist. If death is not immediate, the temperature will rise. Localizing signs may or may not appear. Convulsive seizures may occur in the acute phase of such injuries. The contusions which occur about the midbrain may be contributed to by shifts of the brain stem against the rigid tentorial edges at time of injury, and they may result in a decorticate or decerebrate state with an ominous prognosis.

Manifestations of *increased intracranial pressure* (produced by edema and hemorrhage) may be noted within a few hours; if active hemorrhage is the cause of the compression (see p. 634) these manifestations may be noted sooner. As a rule, the blood pressure rises and the pulse rate decreases (down to 40 to 60 per minute). A sudden decrease in blood pressure, particularly if it drops below normal, is usually serious and may be a sign of impending death. The same may be said of an increase in pulse rate, par-

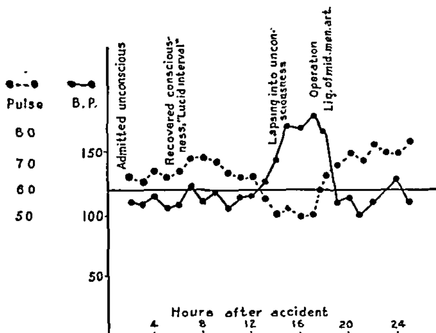


Chart 1. Extradural hemorrhage from the middle meningeal artery. Note that as the patient recovered consciousness (lucid interval) the pulse and blood pressure remained unchanged. The rise in blood pressure and drop in pulse rate at about the fourteenth hour was caused by the pressure effect of the bleeding from the torn artery. While this type of chart is almost pathognomonic of increasing cerebral compression, it should be emphasized that this complex is not always present with such lesions.

ticularly if it rises to above 120 or 130 per minute. The optic disks occasionally swell. The respirations become abnormal and are commonly slow and deep, but may be stertorous or of the Cheyne-Stokes variety.

Signs of compression of the brain may be produced also by the simple accident of rupture of the arachnoid, thus allowing fluid to escape into the subdural space. However, the manifestations of this injury are more apt to simulate those of middle meningeal hemorrhage, except that the rise in blood pressure may not be so great.

In injuries which are fatal, the blood pressure falls and the pulse rate rises as death approaches (Chart 1). Other manifestations of shock, including pallor and cold extremities, become more pronounced. The breathing becomes more abnormal, particularly slower and more irregular. A terminal rise in temperature is commonly noted in patients who have survived longer than a few hours. It is worth emphasis that of all the clinical observations which are helpful in judging such cases the one of prime importance and the one most often neglected in favor of less useful data (such as reflexes) is the *level of consciousness* of the patient. So important is this index of progress that its determination, regardless of the course of vital signs, pupillary reactions, and so forth, often by and in itself dictates surgical measures and exploration for hemorrhage or other fluid collection.

It may be noted that, except in children or in adults with massive scalp hemorrhage, the findings of shock are transient in the patient with head injury and, if persistent, usually point to another site of injury, such as the chest, abdomen, or extremities. It is not safe to ascribe true surgical or hypovolemic shock to the head injury alone.

Fractures of the base of the skull are usually, but not invariably, associated with diffuse damage to the brain. Such fractures are usually serious (because of the proximity of the vital centers) even though the damage is local. Involvement of the facial nerve and nerves supplying the eye indicates basal damage. Injury to the olfactory nerve with subsequent anosmia is common. If the fracture passes through the petrous portion of the temporal bone, bleeding from the ear may be noted. In fact, bleeding from the ear, not arising from the external ear or canal, is in-

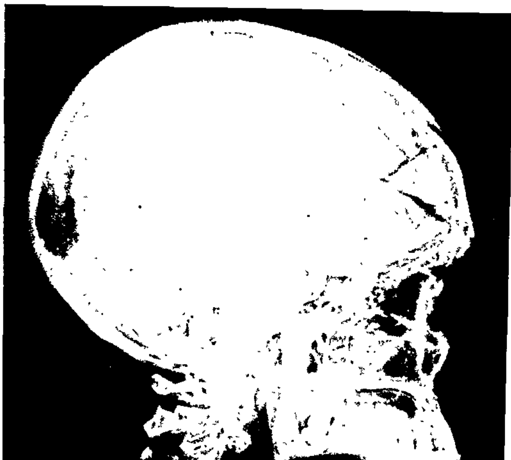


Fig. 9. Depressed skull fracture with complications. This patient suffered a cerebral contusion of the frontal lobes, proptosis of the eye and blindness from orbital involvement, and persistent cerebrospinal fluid rhinorrhea accompanying these serious, depressed, comminuted fractures. Operation repaired the lacerated meninges and sealed the cerebrospinal fluid leak from the frontal sinuses and cribriform plate.

dicative of a basal fracture, usually of the middle fossa.

Bleeding from the nose and mouth suggests a basal fracture if there has been no direct injury to these parts. The escape of spinal fluid from the ear or nose is proof of the presence of a fracture through the base. Orbital ecchymosis and subconjunctival hemorrhage, when distinguished by their configuration from a "black eye" of local trauma, points to an anterior fossa fracture (Fig. 9).

Operative *treatment* is directed toward the removal of extradural, subdural, and intracerebral clots and the control of bleeding. The brain compression syndrome may include:

(*a*) Progressive impairment of consciousness. (It is unnecessary to wait until the patient is profoundly comatose; for example, the appearance of urinary incontinence in an otherwise wakeful patient may be sufficient evidence of deterioration.)

(*b*) Appearance or progression of focal neurologic deficit, such as extremity weakness.

(*c*) Focal ocular signs (the unilaterally dilated pupil) or abducens paresis.

(*d*) Vital sign alteration, as discussed above.

The presence of such a syndrome, complete or in part, is an indication for operative intervention. It is caused by surgically important lesions, such as clots and loculated fluid collection, but it is also caused by the cerebral edema or swelling attendant upon the lacerations or contusions which may be present. It may also be produced by fat embolization or metabolic disturbances such as fluid and electrolyte imbalance. It is often impossible to distinguish between these major categories clinically, and operation must be done. The use of electroencephalography is an adjunct only, and cannot be relied upon to diagnose

a surgical lesion. Cerebral angiography in the patient with head injury has an important place among the diagnostic tools and may disclose or distinguish the presence and nature of intracranial hemorrhage. The introduction of intravenous urea solutions in 15 to 30 per cent concentration by Javid (13) and the administration of U.S.P. urea by mouth or intragastric tube have provided the most useful of many tried procedures to combat diffuse brain swelling. Urea may be helpful in the patients treated by operation as well as in those with the nonoperative lesion of brain edema. The intense diuretic effect of urea requires careful attention to fluid balances in such patients. The presence of active bleeding, or the suspicion thereof, is a contraindication to the use of such urea solutions.

Restlessness is controlled by such drugs as sodium phenobarbital administered parenterally and chloral hydrate or paraldehyde, by mouth or rectum. It should be emphasized that the restlessness of disturbed patients may be due to a full bladder and a desire to void. All respiratory depressants (e.g., morphine) should be avoided. Fluid intake should be kept at body needs. Hot weather, sweating, and food intake vary the requirements. A urinary output of from 0.6 to 1.0 ml. per kilogram body weight per hour should be maintained. Patients in deep stupor should be turned on the side or kept in a Sims' position to permit the tongue and jaw to come forward and secretions to drain out. Maintenance of a clear airway is of utmost importance and tracheotomy is occasionally required. Ordinarily postural drainage or suction through a bronchoscope is adequate. For cyanosis, or when respiration is difficult, oxygen should be given.

In a study of 1,000 consecutive patients with head injury admitted to their hospital, Ulin and associates (14) noted that respiratory embarrassment was the most serious complicating factor; the liberal use of tracheotomy or endotracheal suction will minimize the serious effects of these respiratory complications and often be life saving. The use of lumbar puncture should be individualized. The presence of signs of meningeal irritation, the new appearance or persistence of fever, and the presence of severe headache may be indications for lumbar puncture.

Recent evidence indicates that prolonged confinement to bed does not lessen the incidence of post-traumatic symptoms (15). The degree of activity desired by a conscious and rational patient is usually a safe guide. Activity can be increased gradually when evidences of bleeding have ceased and intracranial pressure is normal.

2. *Extradural Hemorrhage.* In most instances, extradural hemorrhage arises from the middle meningeal artery which is torn by a fracture. On rare occasions a fracture is not present. The occasional occurrence of such a hemorrhage in the posterior fossa needs recognition. A history of at least a short period of unconsciousness followed by a lucid interval of variable duration (2 to 18 hours) is the classical clinical picture observed, but is seen in the minority of cases. Persisting unconsciousness with the development of localizing signs and evidences of increasing intracranial pressure is a more frequent sequence. The patient then becomes stuporous and sinks into coma. The blood pressure usually rises sharply, and this, when it occurs, is perhaps the most valuable diagnostic sign of middle meningeal hemorrhage, with the exception of the periods of unconsciousness just described. The slowing of the pulse rate is a more constant finding. The respirations may become stertorous. Swelling of the optic disks may develop. Localizing symptoms may be observed, indicating that the clot has progressed upward over the motor area; weakness of one side of the face or an extremity (usually the arm) opposite the side on which the hemorrhage is located, constitutes the chief local sign. A unilaterally dilated, fixed pupil, which is an ominous sign, usually on the side of the hematoma, is seen in half the cases by the time operation is performed. It will be noted that most of the manifestations accompanying middle meningeal hemorrhage are in reality those of a gradually increasing cerebral compression. Death may follow in a few hours; for this reason it is important that the condition be recognized promptly and immediate operation performed for the evacuation of the blood clot and control of any active bleeding. The mortality rate following extradural hemorrhage is remarkably high (30 per cent or more).

Schneider and Tytus (16) have made a

study of the causes of this high mortality rate; they conclude that failure to suspect the condition and to operate promptly, failure to realize that the decereberate rigidity pattern may result from an extradural hemorrhage, failure to appreciate that otorrhea or rhinorrhea may mask the symptoms, and lack of familiarity with the condition by all physicians treating head injuries represent factors explaining the poor results.

3. *Subdural Hemorrhage.* Hemorrhage of this type usually arises from rupture of veins on the surface of the brain. The amount of bleeding is extremely variable. Thus the symptoms may arise shortly after the injury, or their appearance may be delayed for weeks or even months.

The mortality of acute subdural hematoma (occurring in hours up to one week) is from 30 to 50 per cent, being higher the more acute the process. Such a mortality is not caused by the lesion in question alone but signifies the mortality of the multiple and complex injuries of such cases.

Much of what has been said relative to extradural hemorrhage may apply to acute subdural hematomas in adults. Fractures are less common, and the mechanism of injury may have been less vigorous with less evidence of trauma about the scalp. In children, the clinical symptoms and signs differ somewhat. The occurrence of vomiting and irritability, the more frequent association of convulsion, the mild change in head size or changes in fontanelle tension, and the development of more frequent retinal hemorrhages are notable differences.

It is in the chronic subdural hematomas that a history of earlier injury is necessary for diagnosis, yet may be overlooked. Blood which persists in the subdural space may become encapsulated and, possibly by osmosis of cerebrospinal fluid, the mass enlarges. The exact mechanism of the formations of such sacs is not fully understood. Evidences of chronically increased pressure then appear. Localizing signs may or may not be present. It should be emphasized that, regardless of signs, subdural hematomas are often bilateral. Evidences of blood in the spinal fluid are frequently lacking and are not essential to the diagnosis. The most common symptoms are those seen in increased intracranial pressure —such as headache, vomiting, irritability, change in personality, sometimes mental deterioration including inattentiveness, forgetfulness, and even stupor or unconsciousness. Weakness of an extremity and exaggerated reflexes on the side of the body opposite the hemorrhage may be demonstrable. Choked disks are usually present. The diagnosis is usually difficult, particularly in the chronic cases, because the trauma producing the injury may be so slight as to have been forgotten. Moreover, symptoms and signs may be few in number and atypical. The electroencephalogram and cerebral angiogram will be useful diagnostic adjuncts (Fig. 10).



Fig. 10. Post-traumatic subdural hematoma. Cerebral angiogram several weeks following a minor head injury. Note the smooth displacement of the cortical vessels from the inner table of the skull and the displacement of the midline vessels to the opposite side. At operation, a large, encapsulated collection of old, liquefied, subdural hematoma was evacuated.

Treatment consists of removal of the blood and fluid through trephine openings. It may be necessary to turn down a flap. In the adult, the sac surrounding the clot need not be removed except with recurrent accumulations, but in the infant the problem is altered. The use of subdural aspiration and trephination may be adequate to control early fluid collection. Persistence of the encapsulated fluid then requires craniotomy with excision of the membranes and expansion of the brain to obliterate the subdural space.

4. *Intracerebral Hemorrhage.* Solitary intracerebral hemorrhages of large size are not uncommon shortly after injury. The evidences of general pressure plus focal findings are present. Exposure of the involved area at operation and, if no surface bleeding is present, puncture and aspiration reveal the accumulation of black liquid blood. A small cortical opening may be required to permit the extrusion of a clot.

The diagnosis of possible intracranial hemorrhage or local compression may be as far as the surgeon can go preoperatively. In the face of indication for operations, viz.: (*a*) open wound, (*b*) depressed fracture, and (*c*) the brain compression syndrome, the surgeon must plan his operative approach to permit proper evacuation of fluid or clot regardless of its final location as discovered at the operating table. The various specialized neuroradiological technics may reduce the uncertainty, but the surgeon must be capable of adapting to the presence of lesions in varying locations and at varying levels.

Late Complications of Head Injury. Elective repair of a cranial defect by premolded radiolucent plates or by methyl methacrylate plates molded aseptically at the operating table is an advance over the metallic plates. Persistent cerebrospinal fluid rhinorrhoea or otorrhoea may demand intracranial repair of the lacerated dura mater at the site of communication. Late post-traumatic epilepsy occurs in 3 to 5 per cent of closed head injuries and 30 to 40 per cent of open penetrating injuries which lacerate the dura mater and brain. Seizures early in the course of an acute injury need not presage the development of late epilepsy but the latter requires careful anticonvulsant regulation.

Post-traumatic Syndrome. Not infrequently, serious symptoms persist for many months after severe intracranial injury. Headache of an inconstant type, exacerbated by fatigue, is perhaps the most disabling complaint. Persistent dizziness, irritability, loss of memory, and lack of initiative are common complaints. There is little correlation between neurologic deficit and this syndrome. Treatment should consist of reassurance, graduated exercises, and other means of rehabilitation (Voris, 17).

Intracranial Neoplasms. These include neoplasms of brain tissue, of the meninges, of cranial nerves, and of the pituitary gland. Other developmental faults such as Rathke pouch tumors, dermoids, epidermoids, and chordomas are not rare.

Roughly half the intracranial tumors have their origin in the supporting tissues of the brain, the glial cells. The gliomas vary widely in gross appearance and cell type and have corresponding differences in rate of growth. All are infiltrating in character and with rare exceptions will recur after removal. In gliomas, as well as in other intracranial tumors, the age of the patient, the site of the tumor, its rate of progress, and its x-ray characteristics, aid in preoperative judgment of the pathological type. Certain of the gliomas, e.g., some astrocytomas and oligodendrogliomas, are slow growing and relatively benign. Others, such as the glioblastoma multiforme, recur rapidly. Some types, such as the medulloblastoma, which is most frequently seen as a fourth ventricle tumor in small children, respond to radiotherapy and may be controlled for a few years.

The tumors of meningeal origin account for perhaps 15 per cent of the intracranial tumors, often invade bone, but are encapsulated tumors which displace the brain and are benign. Their favorite locations are over the vault and at other areas in the base where the arachnoidal villi are numerous (Fig. 11).

Of the cranial nerves, the eighth gives rise to the most common tumor of the cerebellopontile angle, the acoustic neurinoma; the optic nerve and chiasm are the sites of gliomas.

Of the various pituitary adenomas, the chromophobe adenomas of the anterior lobe are most common. These have no secretory function and show their presence by neigh-

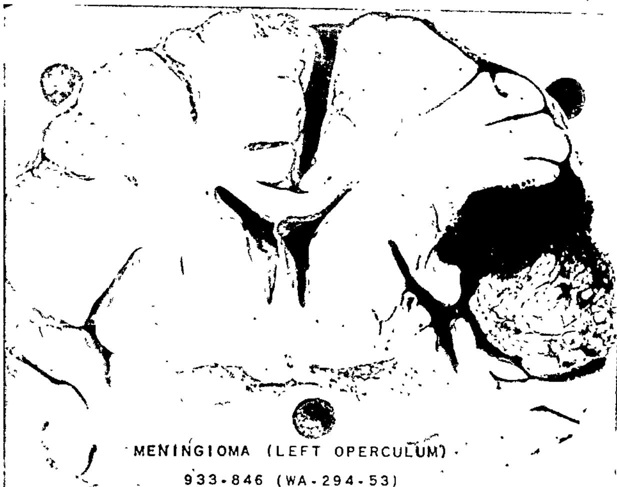


Fig. 11. Hemispheral meningioma. This patient suffered focal epileptic seizures and a progressive speech loss and motor paresis. He died without surgical therapy. Such a favorable meningioma may be totally resected with ultimate recovery of the patient.

borhood signs, such as visual field defects, enlargement of the sella turcica, and disorders of glandular secretion by compression of the remaining cells of the gland. The adenoma which gives rise to acromegaly is composed of eosinophilic cells which do have a secretory function. Most of the basophilic adenomas which are related to Cushing's disease are not large enough to deserve consideration of surgical removal. Malignant adenomas are infrequent, and occur in 5 to 8 per cent of tumors.

The diagnosis of tumor must be considered when the symptoms and signs can be explained by a *single* lesion. If there is evidence of its enlargement by increasing local neurological signs, a tumor should be diagnosed. Finally, if there is evidence of its space-consuming (chorophagic) character, the diagnosis is certain. These final signs are due to intracranial pressure from the size of the tumor or because, even if small, it may be so placed as to obstruct the flow of cerebrospinal fluid. These signs are headache, vomiting, choked disks, enlargement of the head in the young, alterations in the x-ray appearance of the bone from pressure (beaten silver appearance), a cracked pot note on percussion, paralysis of the sixth nerve from distortion, and variable degrees of stupor in the far advanced stages, in which the intracranial pressure may be greatly elevated.

Metastatic tumors are by no means infrequent. The commonest primary lesions are carcinoma of the lung in the male and of the breast in the female.

TREATMENT. The treatment of brain tumors is by operative removal and, for certain types, radiotherapy. The type of tumor and its accessibility are determining factors in the result. Practical descriptions of brain tumors, with classification and treatment, may be

found in the publications by Spurling (18) and Davis (19).

Intracranial Suppurative and Inflammatory Masses. The infectious granulomata, such as tuberculoma or parasitic lesions, are rare and usually masquerade as a brain neoplasm and are treated by surgical excision.

Bacterial infections of bone, meninges, and brain, although not as common as before the development of antibiotics, are dangerous and potentially lethal. *Osteomyelitis* of the skull requires excision of diseased bone and intensive chemotherapy. *Subdural purulent collections* may occur after acute frontal sinusitis or other contiguous infectious foci, and if not promptly recognized by the occurrence of the brain compression syndrome as well as acute systemic reactions to infection, a fatal outcome ensues. Brain abscess retains a high mortality but is more successfully treated now than formerly. Mastoid infection and sinusitis, especially of the frontals, are the common origins; spread to the brain is by an infective thrombophlebitis and less often by contiguity. Other sources are penetrating wounds, osteomyelitis of the skull, or through the blood stream, usually from foci in lung or pleura. The diagnosis is based on the criteria given above for the recognition of a tumor, plus an infectious focus as a primary lesion. Mastoid infections are most apt to cause abscesses in the temporal lobe, less often in the cerebellum. Frontal sinus infections spread to the frontal lobe and occasionally to the temporal. Brain abscesses are treated by aspiration and enucleation; intensive chemotherapy should also be utilized for several days following operation. Eradication of the initiating focus, if present, is a first principle but usually is best delayed until the more lethal brain abscess is successfully controlled.

Surgical Lesions of the Vascular Tree. Saccular and berry or developmental aneurysms commonly lie on the circle of Willis and may manifest themselves (*a*) by spontaneous subarachnoid hemorrhage, (*b*) by cranial nerve paresis (commonly oculomotor nerve when located on the internal carotid artery), and (*c*) by focal neurologic deficit from intracerebral rupture or neighborhood pressure by the mass itself. The lethal nature of recurrent spontaneous subarachnoid hemorrhage when due to intracranial saccular aneurysm requires that patients suffering from unexplained hemorrhage be studied by cerebral angiography. The location and configuration of the aneurysm, if present, will dictate the correct therapy which may be the successful surgical exclusion of the aneurysm from the vascular system to preclude further expansion and hemorrhage. Rupture of such aneurysms explains the large majority of spontaneous subarachnoid bleeding.

Arteriovenous malformations manifest themselves (*a*) by subarachnoid bleeding; (*b*) by focal neurologic deficit, usually hemiparesis; and (*c*) by focal epilepsy. Intracranial bruit may occur in 30 per cent of such cases and is more often associated with such a developmental anomaly than with aneurysm. Angiographic visualization of the intracranial circulation will define accurately these lesions which, when favorably located, may be totally excised. Fistulas between the carotid artery and the cavernous sinus may follow cranial trauma but when spontaneous usually are due to rupture of an aneurysm within the confines of the sinus; the dramatic picture of pulsating exophthalmos ensues together with bruit and cranial nerve paresis. Cervical carotid occlusion and intracranial carotid occlusion are the usual measures required for successful therapy.

Internal carotid artery atherosclerosis may produce signs and symptoms of cerebral arterial insufficiency. In properly selected patients, cervical carotid thromboendarterectomy may re-establish adequate cerebral circulation.

General Manifestations of Intracranial Lesions. Sooner or later in their development and growth, tumors and abscesses (especially the former) will produce an increase in intracranial pressure, whose relation to trauma has already been discussed. Ordinarily, however, trauma produces increased pressure so much more rapidly that the clinical manifestations are quite different. Until tumors do produce signs of increased intracranial pressure, there may be no means of discovering their presence unless, as occasionally happens, focal signs develop. The general manifestations may be listed as shown below. These are nonspecific and of little value in localization of

the intracranial mass responsible. They may be late in occurrence yet all too often they are among the earliest manifestations. The physician must be alert to the possible diagnosis of a mass lesion before these signs and symptoms appear.

1. *Headache.* This is, no doubt, the most common of the symptoms of intracranial disease and may be the first to appear. As the tumor increases in size the headache increases in intensity, though it is intermittent. It may be confined to any part or be found in all parts of the head. From lesions in the posterior fossa causing hydrocephalus, the headaches are frequently suboccipital. With cerebral tumors, the pain is over the vault or frontotemporal area. In early phases of disease before the development of raised intracranial pressure, unilateral headache may have lateralizing value.

2. *Vomiting.* After the increase in the intracranial pressure becomes significant, vomiting becomes a prominent symptom. The vomiting may be projectile, but more characteristic is the fact that it may occur with little or no nausea. It is much more common with subtentorial than with supratentorial growths.

3. *Papilledema.* If increased intracranial pressure has been present for some time, only on rare occasions does a brain tumor fail to produce a choked disk. The "choking" of the disk (papilla) is presumably due to obstruction of the veins of the disk, created by the increased intracranial pressure. Hemorrhage and exudate in the retina are also present and are more important in determining the age of the process than is the amount (number of diopters) of swelling of the optic disk. Secondary atrophy results from persistent pressure.

4. *Convulsions (General).* Although the exact mechanism of generalized convulsions (tonic, clonic, without aura) is not clear, they are frequently observed and are presumably of irritative origin. They are especially common when the tumor involves the cerebral cortex.

5. *Mental Dullness.* As the intracranial pressure increases, there is a tendency for the patient to become mentally dull. Cerebration is slow, and at times the patient may become so stuporous as to be aroused with difficulty. It is not uncommon, however, for a normal sensorium to be retained even in the presence of marked increase in intracranial pressure. Lesions in the temporal lobe are more apt to be associated with mental dullness than lesions in other areas.

6. *Slow Pulse.* Slowing of the pulse rate (presumably of medullary origin) appears late. It is much more common in brain abscesses than in tumor. The rate may be as slow as 45 beats per minute.

7. *Unconsciousness.* A pronounced increase in intracranial pressure with its attendant shifts of intracranial mass may lead to unconsciousness and may progress to deep coma. If it appears suddenly, the possibility of hemorrhage (into the tumor) should be considered; however, this is of infrequent occurrence. More commonly, ventricular obstruction is the cause of the unconscious state.

8. *Miscellaneous Manifestations.* Vertigo and dizziness are frequently produced by an increased intracranial pressure, but on many occasions are focal signs, i.e., produced by lesions involving the eighth nerve, which supplies the semicircular canals. Hiccup, yawning, and sighing respirations are evidences of medullary compression and therefore are usually serious symptoms. Respiratory difficulty of various types may be observed (including cessation). Changes in the blood pressure rarely occur except as an accompaniment of sudden hemorrhage within a tumor, but are more frequently encountered in acute intracranial injury with hemorrhage, as has already been discussed. The presence of increased intracranial pressure over a long period of time produces a thinning of the skull, especially in children, as shown by a "beaten-silver" appearance in the roentgenograms or, more commonly, demineralization of the sella turcica, especially the floor and dorsum.

Important to recognize are the intracranial shifts and herniations which occur with supratentorial masses such as take place at the tentorial incisura. These shifts may cause false localizing signs such as third nerve palsies, hemianopias, hemiparesis, and may also be responsible for severe midbrain compression, hemorrhage, and death.

Focal Manifestations. In order to determine the location of the lesion it is important to determine the presence or absence of the various focal manifestations which are listed

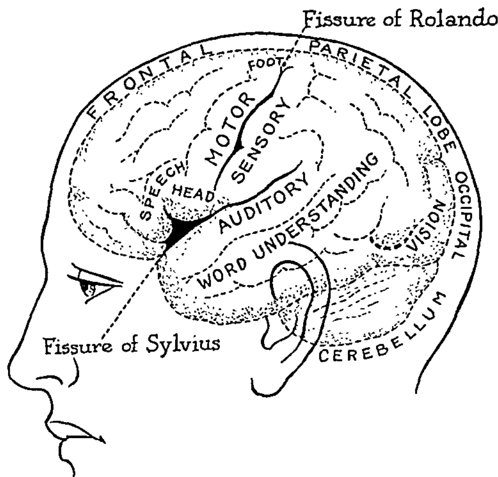


Fig. 12. Diagram of the brain to show its anatomic divisions and a gross localization of some of the important cortical, subcortical centers.

below under the various areas of the brain. Any or all of the general symptoms and signs already described may also be present (Fig. 12).

1. *Frontal Lobe.* One of the most characteristic symptoms of frontal lobe lesions is a change in the patient's personality. The type of change is not always the same, but the development of childish characteristics, a disregard of social propriety, irritability, lack of adaptability, and symptoms and signs of an organic dementia including defective recent memory are commonly observed. Emotional changes, such as the tendency to laugh or cry without ample provocation, are likewise commonly encountered. Unilateral facial weakness and other muscular motor disturbances, particularly of the extremities (on the side opposite the lesion), are usually indicative of a frontal lesion. Pathologic reflexes may be demonstrable; forced grasping is encountered. Speech disturbances, progressing even to complete aphasia, may be present if the lesion is located on the dominant side. Convulsions of the Jacksonian type are particularly common in patients with tumor of the frontal lobe. Anosmia may point to a subfrontal tumor.

2. *Parietal Lobe.* Tumors in the parietal lobe may produce convulsions, but they are usually of the type preceded by sensory aura. Motor deficit can, of course, occur. Sensory disturbances may be present but usually consist of errors in two point discrimination, in which a true hypesthesia does not exist. Astereognosis (inability to identify objects placed in the hand) is occasionally demonstrable. Pathologic reflexes as well as motor and sensory disturbances may be present. Occasionally, aphasia of varied types will be present, but usually only when the tumor is located low down near the fissure of Sylvius.

Deep parietal lesions will produce homonymous visual field defects.

3. *Temporal Lobe.* Lesions in the temporal lobe commonly produce a characteristic defect in the visual field, consisting of varying degrees of homonymous hemianopsia. For example, a patient with a left-side temporal lobe tumor would have blindness on the left side of each retina; this is called a right homonymous hemianopsia because the patient is unable to see objects on his right. Lesions confined to the temporal lobe show a superior homonymous quadrant opsia. Those farther posterior and medially may cause a complete hemianopsia. Hallucinations of smell or taste may occur with deeply placed lesions as may formed and colored visual hallucinations. Temporal lobe seizures may occur and are characterized by repetitive, purposeless, automatic behavior. Facial and upper extremity weakness is often found with temporal lobe lesions.

4. *Occipital Lobe.* Lesions in the occipital lobe commonly produce homonymous hemianopsia which usually does not extend to the center of vision. Visual hallucinations (usually unformed flashing lights) may occur and represent a focal epileptic attack.

5. *Cerebellum.* Ataxia, asynergia, and atonia are characteristic features of cerebellar lesions. When the patient walks there is usually a tendency to fall toward the side of the lesion. Adiadokokinesis (inability to rapidly pronate and supinate the hand) is likewise usually present. Nystagmus is commonly observed. Occasionally the attitude of the head may be characteristic, i.e., flexed toward the side of the lesion with slight rotation so that the chin is pointed to the opposite side. The general symptoms and signs of increased intracranial pressure are usually present to a marked degree when cerebellar lesions are present, because of the obstructive hydrocephalus which is produced.

Knowledge of the sequence and chronology, as well as the tempo of the appearance and progression of signs and symptoms, is indispensable to the diagnosis of mass intracranial lesions. The same may be said of much disease. Progressive mental deterioration, cranial nerve paresis (especially in combination with neighborhood nerves, such as the fifth, seventh, and eighth), progressive motor or speech deficit, involvement of the visual apparatus, and epilepsy of focal or late onset (after 30 years of age)—these are common clues suggestive of an intracranial mass lesion and require full investigation.

Diagnostic Tests. These may be extremely helpful in making a diagnosis and accurate localization of various lesions affecting the brain or spinal cord. Of the various procedures, *spinal puncture* is perhaps most often used. This is performed by having the patient lie in a lateral decubitus position and inserting a needle into the spinal canal, usually through the fourth or fifth lumbar interspace. A pressure reading is always desired; the normal pressure is 80 to 150 mm. of water in adults. Fluid examination for cells and protein, as well as serological tests, is recommended. Spinal puncture is contraindicated in the presence of choked disks.

An effective method of detecting a block in the spinal subarachnoid space is the *Queckenstedt test,* which consists of observations of the pressure while the cervical veins are compressed. If no obstruction is present, the pressure should rise an additional 200 mm. of water promptly with a prompt return. A combined cistern and lumbar puncture will be more effective in discovering a partial block. Such manometric studies are applicable in the study of spinal disease and should not be employed either routinely with all lumbar punctures and certainly not in association with intracranial disease.

Injection of radiopaque substance is frequently used to determine encroachments upon the spinal canal by neoplasms, herniations from intervertebral disks, and the like. Such substances can and should be aspirated from the spinal canal following fluoroscopy and films. Air is enjoying an increasing place in such studies.

Encephalograms are performed by injecting a gas (e.g., air, oxygen, or ethylene) through a lumbar puncture needle with the patient in a sitting position. In this way the subarachnoid space and ventricles are filled with air, and distortions may be noted by the x-ray. The method has risks and should not be employed when increased intracranial pressure with choked disks is present.

Ventriculograms, made by injecting air or oxygen (preferably the latter) into the ventri-

cles, through trephine openings, gives an accurate outline of the ventricles. It is a very valuable aid in the localization of intracranial tumors. However, the procedure is not without danger. In the presence of excessive intracranial pressure, ventriculography is performed rather than insufflation of air through spinal puncture.

Angiography is an equally important diagnostic test and permits visualization of the vascular system via the carotid and vertebral arteries. It is indispensable in the diagnosis of lesions of the vascular tree and is used alone and in combination with the air tests to study all other types of intracranial surgical lesions.

Radioactive isotope technics as introduced by Moore (20), are occasionally helpful in the localization of brain tumors. The radioactive material is detected in the tumor by counting devices.

Apart from the eradication of specific lesions from the brain substance, such as tumor, there are other conditions for which operations on the brain are undertaken:

Epilepsy. This is usually a symptom of a disease process and therapy is directed toward the primary lesion, such as tumor or abscess, and the treatment of the epilepsy is of secondary consideration. In the absence of a progressive disease which in itself may be dangerous to the patient, the treatment of a locally discharging epileptogenic focus may be possible. Such foci may be caused by trauma (often paranatal), developmental deficits in brain structure, acquired focal vascular disease with scarring, cicatrix after tumor or abscess excision. Careful selection of patients with clinical, radiological, and electrical (E.E.G.) evidence of a single focal lesion permits marked improvement from cortical and subcortical resections in cases inadequately controlled by medical management.

Abnormal Movements. Disease processes such as parkinsonism and choreo-athetosis involve complicated neural circuits, details of which are under constant study. As knowledge of the abnormal neurophysiologic integration increases, the surgeon can apply precise technics, such as stereoencephalotomy, to create deeply placed lesions which, by paralyzing one circuit, may balance another and ameliorate the clinical state. The details of one such precise method is described in the monograph of Spiegel and Wycis (21). Others, notably Cooper (22), have utilized less exact methodology to produce successful results in parkinsonism in 60 per cent of cases.

Hypophyseal Destruction. Destruction of the pituitary gland has offered some palliation for metastatic carcinoma, notably of the breast whereby elimination of target organ secretion and some primary secretion by the hypophysis alters the growth potential of the tumor. Pain relief is the most striking benefit achieved. Other conditions have been treated by ablation of the gland, notably juvenile diabetes mellitus for which the operation is at best in its experimental period. The gland is destroyed by direct surgical excision or by irradiation from implanted isotopes placed into the pituitary.

AFFECTIONS OF THE SPINAL CORD

Congenital lesions, such as spina bifida, have already been mentioned (see p. 423). Detailed discussion of these diseases may be found in a publication by Elsberg (23) and Ingraham and Matson (50).

Injuries to the Spinal Cord and Cauda Equina. The spinal cord terminates at the lower margin of the first lumbar vertebra. Below this level the cauda equina occupies the dural canal. Damage to nervous structures occurs in about 10 per cent of all injuries to the spinal canal. In first aid to potential spinal injuries the patient should be handled so as not to alter the alignment of the spine and increase the damage. The neurological findings vary with the site of injury, from the foramen magnum to the coccyx, and with the severity of damage. Bone and/or ligament damage is associated. In the accidents peculiar to civil life we deal usually with closed wounds. In war we deal also with open wounds, but many are fatal because of associated injury to chest and abdomen. Fracture dislocations of the cervical region incurred by diving or in football are common. Compression fractures by crumpling of the spine in acute flexion occur from falls on buttocks and cave-ins in mining accidents.

About 40 per cent of the neurological injuries occur at the thoracolumbar region, particularly at the twelfth thoracic and first lum-

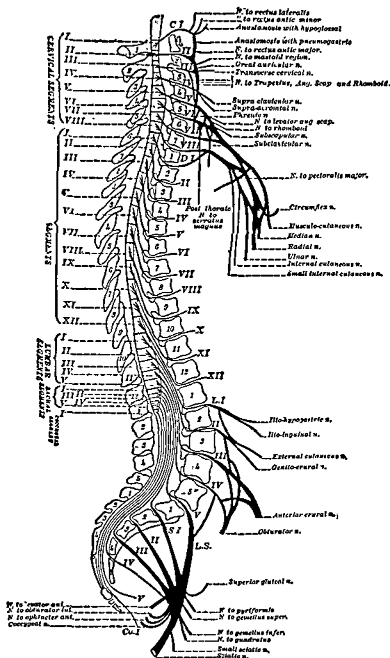


Fig. 13. Relation of the segments of the spinal cord and their nerve roots to the bodies of the vertebrae. (After Frazier and Allen.) Note the progressive upward migration of the cord segments in relationship to the corresponding vertebra. This difference is less pronounced in the infant.

bar vertebrae. Cervical injuries, usually between the fifth and sixth cervical, are next in frequency. In the case of cervical injuries it is not infrequent for severe damage to occur to the cord, and yet x-rays show no evidence of abnormality. *Under such circumstances it* is either an acute extrusion of a cervical intervertebral disc which strikes the cord a blow and produces the paraplegia or a hyperextension mechanism of injury whereby the cord contusion occurs. Any level of the spine may be affected. Dislocation between the atlas and axis and fracture of the odontoid, compression fractures of the thoracic vertebrae, and fracture dislocations of the lumbar vertebrae with caudal injuries are not uncommon. *Much has been learned about paraplegia from* such injuries sustained in World War II.

Morbid Anatomy. The cord may be contused, lacerated, or severed. Hemorrhage, rarely great, and edema follow. Petechial hemorrhages are common. Hemato-

myelia is not frequent. Cavitation following hemorrhage and degeneration appears later and involves several cord segments above and below the injury site (Fig. 13). In direct injuries and penetrations, all grades of trauma may be seen. From missiles, all grades of cord damage may occur, including a physiologic blockade of impulses with a good prognosis (so-called concussion), when the missile has not been in contact with the dura but has struck some part of the vertebra.

Neurological Findings. When the spinal cord is acutely divided there are, below the level of the lesion, complete anesthesia, complete flaccid motor paralysis, loss of all deep reflexes and usually of all superficial reflexes, loss of all bladder control with retention of urine and loss of rectal control. The same picture, but of short duration, may occur if the cord is so damaged as to transmit no impulses past the site of injury. This is called a physiologically complete lesion, although anatomic division may not be present. This phase of "spinal shock" may then recede, leaving the permanent sequela of injury which, if the damage had been severe, may be as complete as in the case of actual cord division. The return of segmental reflex activity signifies the end of spinal shock and the resulting findings may be considered due to structural changes in the cord.

Days to weeks after an anatomically complete lesion, deep reflexes may return and automaticity of bladder and rectum, involuntary movements, and mass reflexes of flexion may occur. In the lesions which are incomplete varying degrees of power, sensation, and some reflexes appear and improvement is slow, continuing over months or years until maximum benefit is obtained.

The upper level of sensory loss and motor paralysis indicates the site of cord injury. Certain major landmarks can be easily remembered. With injuries between the fifth and sixth cervical vertebrae abduction at the shoulder, elbow flexion, and movement of the radial wrist extensor are retained. A sensory level at the ensiform is at the sixth thoracic; the umbilicus is at the tenth thoracic. Injury to the tip of the cord, viz., the conus medullaris, may produce urinary incontinence instead of retention.

That a sensory loss is complete below the lesion can be readily determined if the patient has no sensation on severe flexion of a toe, since deep painful sensation is the last to disappear. The sensory level of the lesion should be promptly noted so that alterations in it may be recognized (Fig. 14). In the examination and detailed x-ray studies, the patient should be spared movements which may exaggerate his cord damage. Lumbar puncture to determine a block (Queckenstedt test) should be performed.

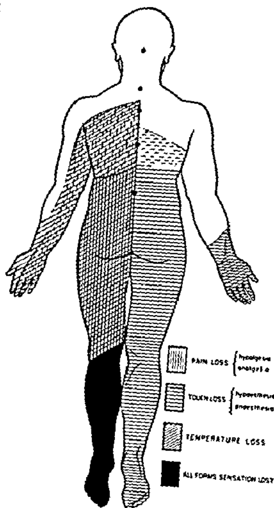


Fig. 14. Sensory charting in spinal cord lesions. Charting of sensory loss using the patterns noted above on plain body diagrams will then permit comparison with various dermatome charts and represent more truthful expression of the deficit.

General Consideration in Prognosis and Treatment. The cord and nerve injury is of more importance than trauma to skeletal structures and requires first thought. Certain axioms are well established. The cord in man

has not evidenced capabilities of regeneration. Certain elements of the cauda equina may regenerate as does a peripheral nerve. *In the first few hours or two or three days, it* may be impossible to differentiate between a cord lesion that is complete anatomically and one that is physiologically complete. If, however, signs of a complete lesion persist longer than this, the lesion may be considered permanent and irrecoverable. Recovery seldom takes place after an injury in which the sensory loss is absolutely complete below the *level of the lesion.*

If, after injury, the paralysis (motor and sensory) is immediate and complete, it may be regarded as permanent. Under these conditions, such operations as laminectomies are misguided efforts. Less severe injuries (incomplete) to the cord may require operation if there is evidence of depressed bone or a positive Queckenstedt, indicating a block. In*complete injuries which become progressively* worse require operation. Intolerable pain may require operation early or late. Operation may be required to unlock overriding facets in fracture dislocations to permit alignment. Skeletal traction for neck dislocations is commonly required. The later man*agement of the skeletal injuries requires* maintenance of the bone and joint alignment by external or internal fixation. Penetrating wounds of the spine require added treatment directed toward débridement and prevention of infection and cerebrospinal fluid fistulas. Evidences of "complete" lesions, yet with *later improvement, may continue longer in* the case of cord concussion than with injury from cord compression or fracture dislocations of the spine.

Nonsurgical Management. These patients are prone to decubitus and urinary tract infections. An air or innerspring mattress, a cradle to remove the weight of bedclothes, smooth, dry sheets, turning every two hours and care of the skin are imperative, beginning at once. Superior care is obtained by the use of pancake turning beds, such as the Foster bed or Stryker frame *which should be provided in all* medical installations treating such cases. Urinary antiseptics should be begun immediately and continued in appropriate doses. In civilian care, tidal drainage methods (Munro) require detailed attention but have proved satisfactory. An indwelling catheter or drainage by a suprapubic catheter introduced midway between pubis and umbilicus is satisfactory *when the above is not practicable.* Emptying the bladder by well-distributed manual compression *may be safe in selected patients* (Browder and Grimes) but not in elderly patients with urinary obstructions and thin vesical musculature. Intermitttent catheterization is justifiable only if carried out as a sterile surgical operation by the surgeon himself. In permanent paralysis an automatic *bladder is desired, and its establishment is* aided by tidal drainage. Ambulation tends to prevent urinary calculi, which develop often in paraplegic patients. Details of spinal cord injuries and their urological aspects may be found in the publications by Prather and Mayfield (24) and Prather (25).

Tumors of the Spinal Cord. Tumors may be primary or secondary. Of the primary *growths about half are benign,* encapsulated, intradural but extramedullary, removable meningiomas or neurilemmomas. If recognized and properly removed, recovery is striking and often complete. The mortality of such operations is very low (under 2 or 3 per cent). Other primary growths may be intra*medullary (gliomas,* ependymomas, angiomas, and the like) or extradural (cysts, lipomas, hemangiomas). Tumors in the caudal region (epidermoids, meningiomas, gliomas, and ependymomas of the filum terminale) may attain giant size. Hour-glass *tumors,* so-called because they consist of extravertebral *portions connected* by a neck through intravertebral foramina or interlaminal spaces, are common. They are most often of neurogenic origin. Oblique x-rays are essential parts of detailed radiographic studies if they are to be recognized. Tumors may *arise in bone* and cartilage, e.g., giant cell tumors, aneurysmal bone cysts, osteoclastomas, osteomata, chondromata, and the malignant chordomas.

Diagnosis of cord tumors, as of brain tumors, involves appreciation of *the fact that* the neurological findings must be explainable *upon the basis of a single, progressing* lesion with, in the later stages, evidence of its space-consuming nature as shown by a positive Queckenstedt test, often with xanthochromic fluid, or obstruction noted after the injection *of radiopaque or radiolucent* substances into

the spinal canal. Pain of a radicular nature, followed by such progressive signs of cord involvement as altered reflexes with sensory changes, is a common finding. The aim of treatment is radical removal by operation. Spinal cord compression may present with a slow tempo of progressive symptoms and signs. If allowed to progress to later phases it becomes a surgical emergency which requires prompt diagnosis and operation to prevent irreparable functional loss. Total clinical paralysis from benign lesions is not incompatible with satisfactory return of function after operation, whereas total paralysis from metastatic malignant disease is rarely if ever benefited. It is of utmost importance, therefore, to discover and treat cord compression before the late stages of paresis.

Secondary tumors, such as metastases from carcinoma of prostate, breast, and pelvis organs, are common. Invasion of the canal occurs in the course of Hodgkin's disease and neoplasm of the hematopoetic system (lymphomas). Granulomas occur, especially in tuberculosis with or without abscess as do parasitic infections and implantations from cerebral tumors (medulloblastomas and other gliomas). Pyogenic abscess is usually extradural and associated with osteomyelitis.

The primary indication for operative decompression in these lesions is developing cord or cauda equina dysfunction from compression. Operation may also be required for pain relief or more rarely for external drainage. The spinal cord may be compressed by an acute collapse of a vertebral body secondary to metastatic disease in which case the cord compression, rather than being due to tumor per se, is due to the bony abnormality. Decompressive operation is frequently indicated in such a case.

Protrusion of an Intervertebral Disk (Nucleus Pulposus). This lesion is responsible in many instances for pain in the lumbar region, and particularly for pain extending down along the course of the sciatic nerve (sciatica). Protrusion of the disk into the spinal canal or intervertebral foramen, with consequent pressure on the nerve roots, is the mechanism responsible for most symptoms. The disks between the fourth and fifth lumbar vertebrae, and fifth lumbar vertebra and sacrum are most commonly involved. Whereas trauma may be an initiating cause or a precipitating factor, a clear history of injury is often lacking. Degenerative changes in the intervertebral disk permit tears in the annulus fibrosus, extension of the nucleus pulposus, and abnormal weight-bearing sprains on the adjacent vertebrae and apophyseal joints. Naffziger and associates (26) emphasize that lifting imposes an enormously increased amount of pressure upon the intervertebral disks because of the leverage action, thereby encouraging damage and protrusion. Other points in the mechanism of the production of the lesion and the pathologic processes are discussed in detail by Hyndman (51) and Falconer et al. (52).

Pain is located over the distribution of the site of the sciatic nerve, being mild at first and becoming more intense as time passes. It may be located in the lumbosacral region, and even in the hip joint. Pain is apt to occur in attacks, it is frequently induced by coughing or sneezing, a feature characteristic of root compression syndromes, whatever their origin. Back pain and extremity pain are the leading symptoms. Limitation of back mobility and aggravation of symptoms by maneuvers which accentuate the protrusion or stretch the involved nerve root are common findings. Neurologic deficit depends upon the nerve root involved and may be slight with a mild weakness and depression of reflex in the segmentally innervated zone. Sensory deficit may be mild. It should be remembered, however, that whereas a unilateral single root syndrome is most common, all degrees of protrusion may occur even to bilateral cauda equina compression, spinal block, and severe neurologic deficit.

It may be difficult to differentiate the condition from a neoplasm of the spinal cord. Lumbar puncture, together with the Queckenstedt test. will be of assistance. The cell count and other spinal fluid findings are relatively normal in nucleus pulposus herniations. The spinal fluid in the presence of a protruding disk frequently has a mild increase in the amount of protein in it. It must be stated, however, that this disease is not the only cause of sciatic pain. Myelography, with the use of radiovisualization contrast technics, is helpful in diagnosis. Electromyographic studies of the involved extremi-

ties give information of muscle electrical potential changes and are useful. Dislocation of the disk is a common cause of upper extremity and neck pain. When severe degenerative disk disease occurs in the cervical area, spinal cord symptoms may develop in the cervical spine (27). A review of these problems is well presented in the monographs of Spurling (28, 29).

Absolute bed rest is often associated with subsidence of symptoms of lumbar disk protrusion and is recommended in the initial attack. Refractoriness to bed rest for two to three weeks, recurrent attacks closely spaced, and moderately severe neurologic deficit are clear indications for operative treatment. In cervical disease, the use of gentle head halter traction is advised initially and operation is reserved for those with the same indications as noted for lumbar protrusions. In their series of 278 patients Spurling and Grantham (29) noted that 85 per cent of operated patients are able to return to work.

Operative Procedures for the Relief of Pain. Severe intractable pain below the costal margins, as produced by malignant tumors and the like, may be eliminated by operative procedures. For this purpose, Spiller and Martin initiated *chordotomy*, i.e., cutting the spinothalamic tracts. The operation is usually performed in the upper thoracic region but may be done in the high cervical area (Fig. 15). Another procedure for the relief of pain, namely, section of the cerebral or spinal nerve roots central to their ganglia of origin, known as *posterior rhizotomy*, is satisfactory in properly selected cases. Prefrontal lobotomy (i.e., section of the frontal lobe) removes the ability to evaluate pain but, if performed on both sides, produces serious changes in personality (30). Precise denervation of most portions of the body with resulting pain re-

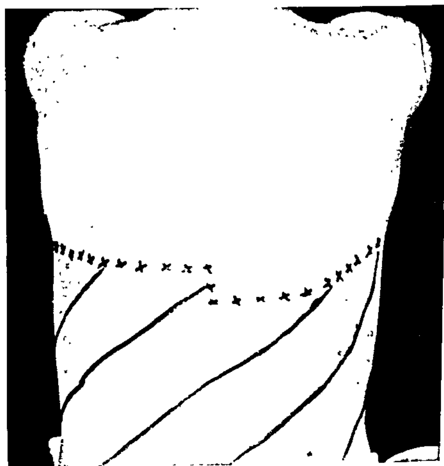


Fig. 15. Thoracic spinothalamic cordotomy. This patient suffered intractable pelvic pain from widespread carcinoma of the rectum. Bilateral anterolateral cordotomy produced complete relief from pain and a level of analgesia as outlined on the trunk. The incision between the scapulae left only a slight scar. (From Stern. California Med., 83:68, 1955.)

lief can be obtained by operations at hand. Bilateral facial pain and upper extremity pain remain exceptions to this, although high cervical cordotomy for upper extremity pain may be gratifying as reported by Horrax and Price (53). Patients should be offered the benefit of appropriate relieving procedures before the ravages of disease become too advanced. The oft-occurring destruction of personality following lobotomy is to be avoided unless addiction is present and pain relief cannot be hoped for from the more precise procedures. Details of mechanisms and control of pain may be found in the monograph by White and Sweet (31).

THE AUTONOMIC NERVOUS SYSTEM

The nerve cells and fibers comprising the autonomic nervous system are concerned in general with the control and regulation of the so-called involuntary or automatic functions of the body—such as the heart activity, in-

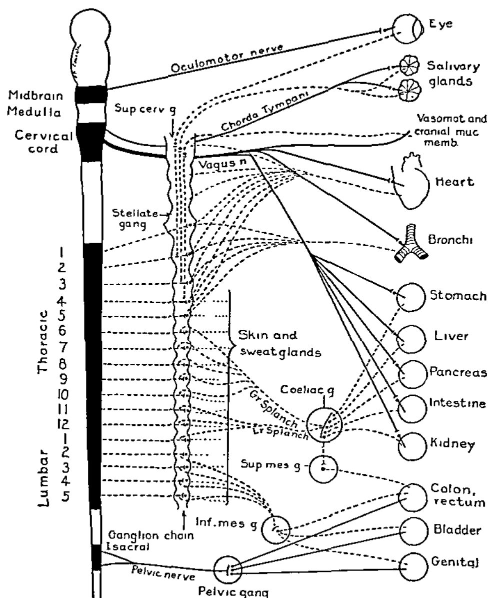


Fig. 16. Schematic drawing illustrating the components of the autonomic nervous system. The solid black lines indicate the craniosacral or parasympathetic nerves, whereas the broken lines indicate the thoracolumbar or sympathetic nerves. (Modified from Kuntz, Autonomic Nervous System, Lea & Febiger.)

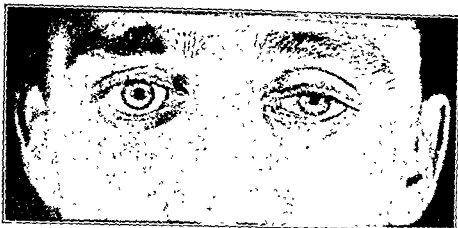


Fig. 17. Horner's syndrome (left eye) produced by gunshot wound injuring the left cervical sympathetic chain. The two important signs of Horner's syndrome, namely, constricted pupil and drooping of the upper eyelid, were present in this patient. Narrowing of the lid slit in Horner's syndrome leads to the false impression that an enophthalmos is present.

testinal movements, respiration, glandular secretion, vasomotor caliber, and sweating (Figs. 16, 17). It should be emphasized, however, that many of these involuntary functions (particularly digestive and endocrine) are also influenced by hormones of various types. Of great importance is the fact that in its control of important and vital visceral functions, the autonomic system is greatly influenced through the emotional states and through the stresses and strains to which the individual is exposed in his work and play. This important influence is not only able to produce *abnormal function* with its resultant symptoms but is probably able to initiate definite organic visceral and peripheral disease which are of great surgical interest and importance. Of great clinical importance, too, is the fact that the autonomic nerves carry impulses of visceral pain, which is discussed later in this chapter, and can frequently be abolished by severing the appropriate fibers. Though the autonomic system is a complex ramification of nerve cells and fibers, there are certain general anatomic features which are simple. One may identify three elements in the autonomic system aside from their central sources in the brain and cord; 1. fibers (preganglionic) which connect these centers with 2. ganglion cells outside the central nervous system and 3. fibers (postganglionic) which connect these ganglion cells with the end organs. The automatic system is usually divided into two groups: (*a*) the sympathetic or abdomino-thoracic-cervical chain (thoracolumbar outflow), and (*b*) the parasympathetic or craniosacral group. These two divisions have a different segmental origin and have antagonistic functions, as will be mentioned below. (It should be noted that the word sympathetic is often loosely used as an all-inclusive term synonymous with autonomic. It is used in this chapter to designate only one part of the system as opposed to its complementary part, the parasympathetic.)

Because of the antagonistic character of the functions of the two systems (sympathetic and parasympathetic) it is obvious that a clear conception of the disease processes associated with these systems is dependent upon an accurate anatomic discrimination between the two. The fibers of the two systems may be identified separately at the points of origin, but distal to the prevertebral ganglia (celiac, pulmonic, and so forth) this is impossible.

The *sympathetic chain* is so-called because its ganglion cells are arranged in a chain on each side of the vertebral bodies in the form of tiny ganglia which are called paravertebral ganglia. In general, the fibers entering the ganglia are called preganglionic or white rami communicantes, and those leaving are called postganglionic or gray rami. In the neck there are three pairs of ganglia: the superior, the middle, and the inferior cervical, and in the thorax, twelve, one for each segment. Occasionally the inferior cervical and the first thoracic ganglia are united into one, which is

known as the stellate ganglion. In the lumbar region, the number of ganglia on each side is variable, but usually four.

The sympathetic fibers supply the various viscera via special nerves and plexuses. The innervation of the heart (sensory as well as motor) is derived from the cardiac plexus which receives the superior, middle, and inferior cardiac nerves (from the superior, middle and inferior cervical ganglia respectively) and also thoracic cardiac nerves from the first to the fifth thoracic ganglia. In addition to these fibers the cardiac plexus receives branches from both vagi (parasympathetic). The celiac (solar) plexus, which surrounds the celiac artery and overlies the aorta at this point, is the most extensive of the prevertebral plexuses. It is supplied primarily by the greater splanchnic nerve which is formed by the union of fibers from the fifth to the ninth or tenth thoracic ganglia. However, the celiac ganglion also receives parasympathetic fibers (from the vagus). There is a series of small plexuses, including the aortic, ureteral, hypogastric, and iliac, which are for the most part extensions of the celiac plexus lying in approximation with the aorta. The abdominal organs are innervated by this series of plexuses, but also receive parasympathetic fibers from the vagi, some of which enter the plexuses and some of which do not.

The sympathetic fibers going to the periphery (skin, muscle, blood vessels, sweat glands) are distributed largely through somatic nerves, i.e., the peripheral (spinal or cranial) nerves which carry voluntary motor and ordinary sensory impulses as well. The sweat glands (supplied only by the sympathetics) comprise one of the few organs which definitely do not appear to have also a parasympathetic innervation.

The *parasympathetic system*, which consists primarily of the craniosacral portion of the autonomic system, innervates, by means of the vagus and pelvic nerves, practically all the thoracic and abdominal organs which likewise have a sympathetic innervation. As mentioned in the preceding paragraph, the thoracic and upper abdominal organs receive their parasympathetic innervation by the vagus nerve which supplies fibers either directly or by traversing the prevertebral ganglia. Shortly after piercing the diaphragm, the vagus nerves divide into three main divisions: left, middle, and right. The left and middle branches of the left vagus innervate the fundus and pyloric region of the stomach, respectively, and the right branch passes to the liver. The left and middle branches of the right vagus go to the stomach, but the right enters the celiac ganglion (Kuntz, 32). Within the wall of the digestive tube are two systems of plexuses (the submucous or Meissner's and the myenteric or Auerbach's) which are associated with peristalsis and glandular secretion. The nerves supplying these plexuses are preganglionic, arising from the vagus and sacral nerves. The pulmonary plexus which distributes fibers to the lungs (particularly the bronchi) is really continuous with the cardial plexus, but consists primarily of vagus fibers. The pelvic nerve arising from the sacral nerves is distributed to the distal part of the colon, the bladder, and perhaps to parts of the genital system.

Functions of the Autonomic System. These are manifold and for the most part motor (efferent), but also include sensory (afferent) impulses which are important in initiating reflex activity and the sensation of visceral pain which, as mentioned previously, is frequently referred to skin areas. The sensory impulses that, of course, reach consciousness pass over afferent fibers which, strictly speaking, do not belong to the autonomic system but belong to the cerebrospinal system and are merely in the same nerve trunks (such as the splachnic nerves) with the efferent fibers. These sensory fibers have their cell stations in the posterior root ganglia as do all other somatic sensory fibers. Motor function is of two kinds, excitatory and inhibitory. A functional or physiologic balance between these two activities is maintained by the opposing innervation of the sympathetic and parasympathetic systems, with one or two exceptions (e.g., the sweat glands), which is controlled in part by the higher centers (anterior hypothalamus parasympathetic and posterior hypothalamus sympathetic).

Motor Functions. The motor functions of the *sympathetic system* as contrasted to the parasympathetic system comprise acceleration of the heart rate, arterial constriction, inhibition of intestinal peristalsis and secre-

TABLE 1. The Balanced Motor Function of the Autonomic System

Organ		Sympathetic	Parasympathetic
Heart (rate)		Acceleration	Slowing
Intestines	peristalsis, secretion	Inhibits	Stimulates
Anal sphincter		Contracts	Relaxes
Urinary bladder	wall	Relaxes	Contracts
	sphincter	Contracts	Relaxes
Eye	pupil	Dilates	Constricts
	lid slit	Widens	Narrows
Arteries		Constricts	Dilates (?)
Sweat glands		Stimulates	——
Bronchi		Dilates	Constricts

tion, contraction of the bladder and anal sphincters, and so forth (Table 1). There is considerable evidence that sympathetic stimulation through excitation of the adrenals causes contraction of the spleen with consequent outpouring of blood. It is likewise responsible for the outpouring of epinephrine which occurs during excitement. Epinephrine has, in general, an action similar to that of the sympathetic nerves, i.e., it is responsible for liberation of glucose from the liver, for increases in the heart rate, and inhibition of digestive secretion. The sympathetic system is important in the maintenance of vital processes of the cells of skeletal as well as smooth muscle, and has a definite effect on muscle metabolism (Kuntz, 32). Years ago, Cannon emphasized the fact that the bodily functions which are stimulated by the sympathetics are those necessary for the efficient mobilization of forces and energy, which are required in times of stress (mental as well as muscular, but especially the latter). Important also in this way are the emotional states, such as fear and rage.

The motor functions of the *parasympathetic system* include such activities as slowing of the heart rate, excitation of the digestive glands, intestinal peristalsis, contraction of the bladder and rectum, along with relaxation of their sphincters, and the like (Table 1).

Sensory Function. Although of less physiologic significance than the motor, the sensory function of the fibers, which are anatomically associated with the autonomic nervous system, is nevertheless important. For example, the integrity of many reflex arcs is dependent upon sensory stimulation. Moreover, visceral pain is obviously dependent upon afferent fibers for transmission and may be eradicated by severance of these fibers which travel in anatomic trunks. Visceral pain may be intense but because of the relative sparsity of nerve ending population in the viscus compared with somatic structures, and so forth, is poorly localized; because of this fact it is often referred to parts of the body other than its site of origin (Fig. 18). In addition to visceral pain, the sensory fibers may carry impulses which reach consciousness and are perceived as discomfort, or fullness, and the like: in many hypersensitive individuals impulses due to normal peristalsis are perceived. The various types of visceral sensation are important in the diagnosis of abdominal disorders, particularly those of nonorganic or functional nature.

Additional data on the anatomy and physiology of the autonomic system may be found in the books by Larsell (33), Kuntz (32), and Ranson and Clark (34).

Disorders of the Autonomic Nervous System. There are a number of diseases whose pathogenesis is associated, at least to a great extent, with dysfunction of, or perhaps a lack of balance between, the sympathetic and parasympathetic nervous systems, even though the exact relationship in most instances is poorly understood. They are discussed in detail in the monograph by White, Smithwick, and Simeone (35).

Megacolon (Hirschsprung's Disease). This disease, consisting primarily of marked dilatation of the colon, is a congenital lesion starting soon after birth or in early infancy. It must be differentiated from acquired megacolon which usually does not occur until the

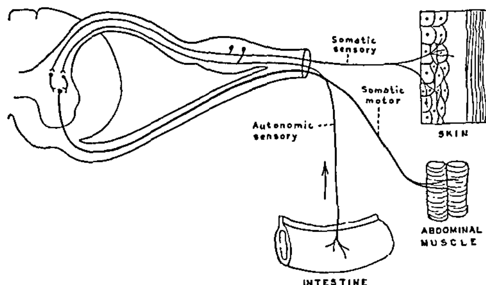


Fig. 18. The nerve pathways producing referred pain and involuntary muscle spasm. The impulse originates in the intestine or other viscus and travels along the autonomic sensory fibers (indicated by the arrow) to the central nervous system. Here it reaches ganglion cells which normally are excited by impulses reaching them over somatic pathways entering the central nervous system at the same level. The pain is experienced as coming from the region supplied by these somatic fibers. The activation of these central sensory cells provokes reflex muscular contraction by way of the somatic motor nerves; this reaction is called involuntary muscle spasm.

age of two or more years. Although absence of ganglion cells of the myenteric plexus was suggested years ago (Cameron, 1928) the major credit for solution to the various problems of this disease should go to Swenson (36) because of the curative operation which he has devised.

The patient may have few symptoms in spite of the fact that the dilatation may be enormous and affect the entire colon. Constipation is, of course, universally present except that diarrhea caused by expulsion of fluid contents of the ileum around the solid impacted fecal masses in the colon may occasionally develop. Very little pain is experienced in spite of the fact that peristalsis may be very vigorous indeed. The degree of abdominal distention varies with the degree of dilatation of the colon. Symptoms including headache, nausea, and vomiting occur occasionally but are rare. In neglected cases, severe malnutrition may develop. Rectal examination is negative; the fecal mass itself cannot be felt (except through the walls of adjacent loops of colon). This finding helps to differentiate the lesion from acquired megacolon in which condition the fecal mass is palpable just inside the anal sphincter. Passage of the fecal material into the rectum is prevented by a functional obstruction located in the upper rectum; this obstruction is caused by faulty peristalsis resulting from absence of the ganglion cells. The dilated colon ends in a narrow segment, usually of upper rectum, which can be identified as the point of the obstruction radiologically by barium enema (Fig. 19), providing films are taken in the proper plane.

Treatment, as advised by Swenson, consists of resection of the aganglionic area (from the rectum to well above the narrowed segment even to the splenic flexure) and anastomosis of the proximal colon to the rectal stump just above the sphincter; this is best accomplished by a pull-through type of procedure which places the anastomosis just above the sphincter, but preserving it. Results are excellent in 80 to 90 per cent of cases, provided the diagnosis is accurate. The danger of giving tap water enemas in provoking "water intoxication" has been mentioned on p. 160.

Vascular Disease of the Extremities. These diseases have already been discussed in

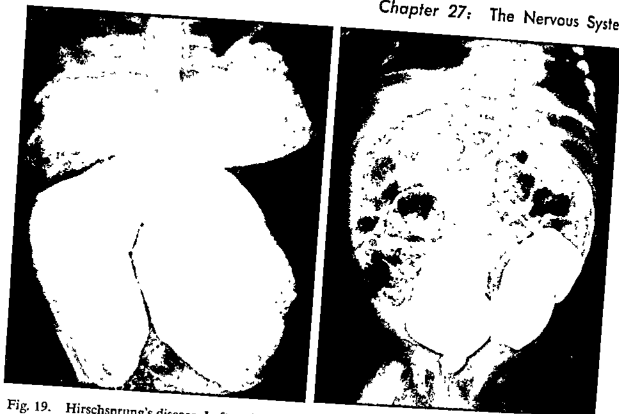


Fig. 19. Hirschsprung's disease. Left, redundant dilated colon is revealed by barium enema. Right, after partial evacuation of the barium. The constricted segment of upper rectum is outlined by the barium.

Chapter 25. In Raynaud's disease, particularly, it is assumed that vasoconstriction of the smaller vessels, produced presumably by overstimulation of the sympathetic system, is an important factor in the pathogenesis of the disease. It is thought by some that the fault is a local one in the vessels themselves in that patients suffering from Raynaud's disease have been found to be unusually sensitive to adrenalin. It should be emphasized, however, that in many instances organic obstruction of the vessels also exists as a late manifestation. On the other hand, in patients with definite organic changes in the vessels, such as Buerger's disease, vascular spasm often plays an important role. Insofar as vasoconstriction is present in some patients with obliterative vascular disease, a disorder of the autonomic system is assumed also to be present. The various diagnostic methods have been discussed in Chapter 25.

Carotid Sinus (Body) Syndrome. The carotid sinus, which exerts a reflex regulatory effect on the blood pressure and heart rate, has connections with the vagus nerve, the cervical sympathetic chain, and the medulla through a branch of the ninth cranial nerve. It may become hypersensitive and give rise to symptoms. Manifestations consisting of weakness, dizziness, fall in blood pressure, and unconsciousness with or without convulsions, occur in attacks. Pressure over the bifurcation of the carotid may reproduce an attack. The cardio-inhibitory reflex which is mediated through the vagus nerve can be abolished by atropine. However, correction of the cerebral type requires excision of the periarterial tissue at the carotid bifurcation.

Tumors of the Carotid Body. These lesions are comparatively rare, but are important because many are malignant or potentially so, yet are associated with a good prognosis when completely removed. It is often very difficult to differentiate benign from malignant lesions microscopically. Most of them produce no symptoms other than gradual growth of the tumor. Despite their location at the carotid bifurcation, these tumors rarely produce symptoms of the carotid sinus syndrome; fainting is rare. Clinically, it may be difficult to differentiate these tumors from a branchial cleft cyst. However, they are located deeper in the neck than branchial cysts and frequently project into the pharynx,

sometimes producing obstructive symptoms. Accordingly, they are best palpated bimanually, with one finger in the mouth. Complete removal of the tumor will require ligation of the internal carotid in about half the cases. Since ligation of the internal carotid can be associated with hemiplegia and death (particularly in the older group), excision of the tumor may at times be undesirable, particularly since no more than 10 per cent of these tumors are malignant. Unfortunately, however, experience shows that even benign tumors ultimately lead to death of the patient in a large percentage of cases. To reduce the risk of carotid ligation it used to be customary to compress the vessel for a period every day for several days to help establish collateral circulation before operation. This procedure was seldom effective. However, since blood vessel grafting can now be carried out so successfully, operation is no longer hazardous and is carried out with little reservation. A homologous (preserved) arterial graft or synthetic prosthetic tube thus permits safe removal of the tumor, even if resection of the carotid is required. Details may be found in an article by Lahey and Warren (37).

MISCELLANEOUS DISORDERS. It is possible that many of the disorders of intestinal peristalsis, including especially spastic colon, as discussed in Chapter 31, are due to an imbalance of the sympathetic and parasympathetic innervation, resulting, perhaps, in a defective peristaltic mechanism.

Scleroderma, a rare disease, is assumed by many to be due to a derangement of the sympathetic nerve supply to the skin. Manifestations consist of the deposition of a dense fibrous layer beneath the skin, associated with a sclerosis of the smaller arteries. The skin may become pigmented, the extremities cyanotic, and the face masklike. Edema is usually present but is not of the pitting type. The outcome is frequently fatal, but sympathetic neurectomy has been devised for certain types of the disease.

OPERATIVE PROCEDURES UPON THE AUTONOMIC SYSTEM. Perhaps the earliest significant operation upon the autonomic nervous system was performed by Jaboulay (38), who resected the cervical sympathetic chain and ganglia for exophthalmic goiter. This procedure has, of course, been supplanted by subtotal thyroidectomy and medical treatment (radioactive iodine). A few years later, lumbar sympathectomy was recommended (Royle) for spastic paralysis of the lower extremity, but results are not good. Sympathectomy was also recommended (Leriche) for *scleroderma,* asthma, and a type of polyarthritis with vascular deficiency to the extremities. Sufficient reports are not available to determine the efficacy of the operation in these diseases. Lumbar sympathectomy combined with excision of the presacral plexus is quite effective in the treatment of various types of *pelvic pain,* especially those of uterine, tubal, and ovarian origin. Section of the appropriate sympathetic nerves has been successfully performed for *localized hyperhidrosis.* Sympathectomy is fairly efficient in relieving the shortening, atrophy, and cold skin of a limb paralyzed by *poliomyelitis.* Presacral neurectomy is sometimes performed (Learmonth) for *spasm of the neck* of the bladder in "cord bladders." Pudendal nerve block or section may be a superior procedure.

Periarterial sympathectomy was popularized by Leriche in the treatment of spastic vascular disease of the extremities but cannot be considered logical since the nerves supplying the vessels enter at numerous points and do not traverse the entire length of the artery. On the other hand, sympathectomy (i.e., removal of ganglion or preganglionic fibers) is a well-established procedure. The better results which are being obtained are produced by a more accurate choice of patient for operation and improvements in operative principles. The indications for sympathectomy in vascular diseases may be summarized to include Raynaud's disease when there is no marked structural damage to vessels, Buerger's disease (except in the acute stage) when good collateral reserve is present, vasospastic painful limbs resulting from poliomyelitis, causalgia (including Sudeck's atrophy) arterial emboli, arteriovenous aneurysms, hyperhidrosis, and certain cases of early gangrene due to arteriosclerosis. It is usually preferable first to demonstrate a favorable effect with local anesthetic injection of the sympathetics, as noted by skin temperature or oscillometric readings, before sympathectomy for this condition. In the upper extremity,

section of the whole rami from the second and third thoracic nerves (Telford) and removal of the proximal segments (Smithwick) of the second and third thoracic nerves, i.e., preganglionic section instead of sympathectomy has been effective, as long as the sympathetic trunk below the third thoracic ganglion is sectioned. Improved results, however, are obtained when the ganglionated chain itself is excised; *although entailing the production* of Horner's syndrome, it does not in man sensitize the end organs to circulating epinephrine as was thought earlier. An important concept of the pupillary fibers' anatomy as related to thoracic sympathectomy is presented by Palumbo (54). In the lower extremity, it is now agreed that removal of the sympathetic trunk with the lumbar ganglia as performed with very little modification for the past several years is an effective procedure in the various vascular lesions mentioned above. The good results are due for the most part to the vascular dilatation obtained, including particularly that of the collateral vessels.

Blockage of the cervical sympathetics by *injecting the stellate ganglion* may be beneficial for selected cases of cerebral thrombosis and cerebral embolism (Gilbert and de Takats, 39; Naffziger and Adams, 40). Paravertebral injection of thoracic nerves is useful in the treatment of the *pain caused by aneurysms and aortitis*. Gage (41) has reported relief of pain and more rapid recovery in acute pancreatitis after paravertebral block of the sympathetic chain. Splanchnic nerve section may be quite effective in the relief of pain caused by chronic pancreatitis. The hypogastric plexus may be removed for intractable pain arising in the bladder or internal sex organs, the lumbar sympathetic chain for painful vascular lesions in the lower extremities, and the cervical or thoracic system for angina, causalgia, or certain types of vascular pain. When disease of viscera and vascular systems involves also the somatically innervated structures, as is usually the case with malignant neoplasms and so forth, sympathetic blockade or section will fail to produce complete pain relief. *Success with cases* of locally confined disease by such blockade is reviewed by Trimble and Morrison (42).

Although not all surgeons performing sympathectomy for *essential hypertension* report good results, the majority do. De Takats and associates (43) report 85 per cent good results in 55 patients in Group I (age below 40 years) who had minimal organic damage with diastolic pressure occasionally above 100 mm. Hg. In 123 patients in Group II (age from 20 to 55 years) with moderate vascular sclerosis in all organs and a diastolic pressure *which could* not be *lowered below* 110 mm. Hg by any method, good results were obtained in 75 per cent of cases. In 24 patients in Group III with retinal hemorrhages, papilledema, fixed diastolic pressure of more than 120 mm. Hg and poor renal function, there were no good results. Zintel and associates (44) report similar results. In their series the five-year survival rates were as follows: Group I, 100 per cent; Group II, 85 per cent; Group III, 86 per cent; Group IV, 63 per cent; and Group V, 45 per cent. They conclude that survival rates are good enough even in Groups IV and V to justify sympathectomy for patients in those groups. Over half the patients having sympathectomy for hypertension have definite improvement in symptoms; *headache is the symptom most* improved after operation, having disappeared in over 90 per cent of Learmonth's series (15). The hypertension may decrease, but in few patients does it reach normal (Evelyn and associates, 45). Postural hypotension is *perhaps the most significant disadvantage of* the operation, being particularly troublesome for the first few months; it may be prevented to some degree by belts or pads worn around the abdomen.

In the surgical treatment of *essential hypertension*, numerous technics have been adopted, but the method recommended by Smithwick (46) appears to be superior to others. De Takats (43) reports his best results in "the post-eclamptic or post-toxemic type of hypertension in women who obviously had organic vascular disease." He likewise obtained good results in "the early juvenile type of hypertension with minimal or not detectable organic changes and with complete response to sedation." Results were good in the latent nephritic type of hypertension. However, results were poor in the malignant phase or the late benign phase of hypertension *with rigid arteries*. In selected

cases of unilateral renal disease complicated by hypertension, nephrectomy may be effective in lowering the blood pressure. The introduction of *blood-pressure reducing drugs* has greatly reduced the number of patients with hypertension seeking operative treatment. A survey of the clinical groupings and the results of operation compared with nonsurgical treatment in 2,227 cases followed five or more years is presented by Smithwick and associates (47). The selection of patients for operation is best made from those with intermediate grades of severity of disease in the cardiac, renal, and cerebral vascular systems and function. The 10-year follow-up of White (48) demonstrates that the methods of 10 years ago applied to comparable patients was less satisfactory than sympathectomy of the Smithwick variety. This is the case in the so-called "Goldblatt" kidney described by Goldblatt years ago.

It must be apparent from the great diversity of operative procedures noted above, that much remains unknown of the anatomy and physiology of the autonomic system. Predictable results following severance of specific fibers must depend on specific knowledge of the impulses they carry. This type of investigation will undoubtedly contribute greatly to the surgery of the sympathetics in the years to come and will extend the field of many other types of disease.

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28

LIVER, GALLBLADDER, AND BILE DUCTS

Liver
Gallbladder
The Bile Ducts

LIVER

The liver is the largest organ in the body and, perhaps, performs more functions than any other organ. It is necessary for life; its removal results in death of the animal within 24 hours.

Anatomy. There are two major lobes, the right being much larger than the left. On the inferior posterior surface is an area designated as the quadrate lobe; on the posterior surface is a small lobe identified as the caudate lobe (Fig. 1). The hepatic artery branches into the right and left before entry into the inferior surface of the liver. The portal vein divides in 90 per cent of cases

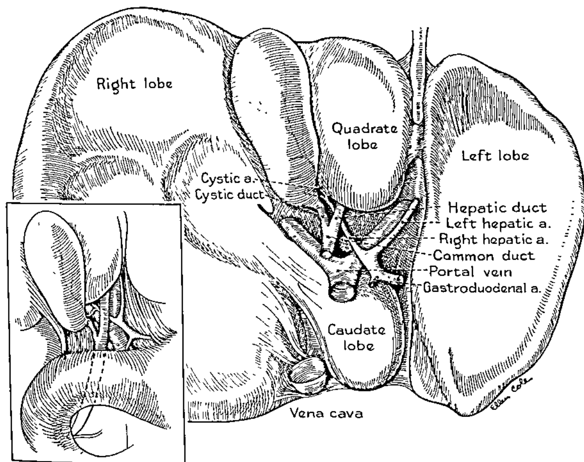


Fig. 1. Anatomy of the ventral surface of the liver.

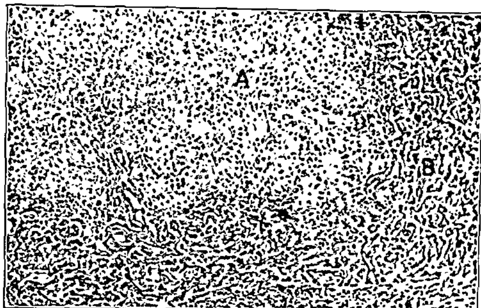


Fig. 2. Photomicrograph (biopsy from operation) to illustrate the remarkable regenerative power possessed by the liver. The patient had been jaundiced for several weeks because of an accute hepatitis of unknown etiology. Represented at A are recently regenerated cells; the portion of the section marked B represents a compressed mass of bile ducts and remains of necrotic hepatic cells. In the process of hepatic necrosis, the bile ducts are the last to be destroyed; the deeper staining tubular structures probably represent newly regenerated bile capillaries. It is probable that considerable fibrous tissue will be deposited in this area, B, and in time, the liver will present a picture like that of cirrhosis.

before it enters the inferior surface of the liver; in the remainder of cases it enters the liver before dividing. The reverse is true for the common duct, inasmuch as the right and left intrahepatic ducts join in 90 per cent of cases before leaving the liver surface.

Physiology. Over 40 functions are known to be performed by the liver (1); no doubt there are many, many more unknown. The liver probably has a wider margin of safety from the standpoint of the amount of tissue necessary for the performance of its functions than other organs, but this wide margin of safety is obviously necessary in times of stress, such as illness and excessive exertion. It is one of the few organs which has the power to regenerate rapidly after injury (Fig. 2). For example, Mann and associates (2) and others have proved that after removal of 70 per cent of an animal's liver, regeneration takes place so rapidly that the normal size is regained within a few weeks following removal.

1. *Carbohydrate Metabolism.* Our knowledge of this important function of the liver was initiated by Claude Bernard in 1857. The liver is able to form glycogen (a carbohydrate) from various other substances, such as hexose sugars, lactic acid, and pyruvic acid (glycogenesis), and is able to produce glucose from glycogen (glycogenolysis). The liver is an important storehouse for glycogen —a ready source of energy. The liver is also able to form glycogen from substances other than carbohydrates, such as amino acids and glycerol fractions of fats (glyconeogenesis).

2. *Secretion of Bile.* The average daily output of bile varies between 600 and 800 ml. per day. It contains bile acids and salts, bile pigments, nucleoproteins, lipids, various electrolytes, urea, ammonia, vitamines, enzymes, and innumerable detoxified or conjugated substances.

3. *Protein Metabolism.* Amino acids resulting from digestion in the intestinal tract are carried to the liver where they are stored and converted to proteins or deaminated. The parenchymal cells of the liver are the primary sites of formation of plasma proteins, such as albumin and fibrinogen; plasma globulins are formed by the Kupffer cells. The amino acids not required for protein synthesis are broken up by splitting off the amino groups—NH_2 (deamination); certain amino acids, such as leucine, isoleucine, and tyrosine, are oxidized as fats. The split-off amino groups are con-

verted to urea, most of which is excreted in the urine as waste. The presence of xanthine oxidase (an enzyme necessary for production of uric acid from nucleic acid or nucleoprotein) in the liver suggests that uric acid may be formed primarily in the liver.

4. *Metabolism of Vitamins.* Carotene in the ingested food is converted into vitamin A by the liver, which also stores it. The liver is probably responsible for the phosphorylation of thiamine to thiamine pyrophosphate, an important coenzyme. Bile is necessary for the proper absorption of vitamin D, which is stored to a slight extent in the liver. Vitamin K is utilized by the liver in the synthesis of prothrombin, which is necessary in the process of blood coagulation.

5. *Fat Metabolism.* The liver forms cholesterol and is concerned with the esterification of free cholesterol. In certain liver diseases the power to produce cholesterol ester is lost. Fats are transported in the body partly as phospholipids, which are formed in the liver and intestinal mucus (3). If certain substances are not available, the liver is unable to form phospholipids and neutral fats are deposited in the hepatic cells. Lecithin, the most abundant phospholipid, is formed in the liver. Fatty acids are oxidized by the liver to ketone bodies. About one third of the carbohydrate brought to the liver by the portal system is converted into fat (lipogenesis).

6. *Blood Formation and Coagulation.* In fetal life, the liver is active in the formation of erythrocytes, but in the postnatal period, this function is lost. The liver is the primary site for the storage of iron, copper, and other products necessary for the production of hemoglobin and erythrocytes. As noted above, the liver synthesizes prothrombin (from vitamin K) and stores it. Likewise, it forms heparin, which is important in preventing intravascular clotting. The importance of the liver in hematopoiesis is clearly demonstrated by the effect of liver extract on pernicious anemia.

7. *Detoxification.* Harmful products may be detoxified by oxidation or reduction by the liver or by combination with other products to form a less harmful product (conjugation). The sulfur liberated from proteins in the food is converted to inorganic sulfate. Bacterial action on certain products of digestion may produce toxic substances—such as phenol (from phenylalanine and tyrosine), indole, and skatole (from tryptophane). The liver conjugates these substances with inorganic sulfate to form ethereal sulfates which are excreted in the urine.

8. *Reticuloendothelial Function.* The Kupffer cells (part of the reticuloendothelial system) of the liver are able to engulf and destroy numerous organisms which may be brought to it from the intestinal tract by way of the portal venous system. The Kupffer cells are active in the destruction of erythrocytes and formation of bile pigment. These cells may also aid in the reparative processes in the liver by means of fibroblastic activity. By means of the gamma globulin produced by the Kupffer cells, the liver aids greatly in defense of the body against infection.

9. *Miscellaneous Functions.* The liver is important in the alteration of blood volume since it can store large quantities of blood. It can exert a role on body fluids because it inactivates (by conjugation) estrogenic steroids and the antidiuretic principle of the pituitary gland. The liver exerts an important role in the regulation of osmotic pressure because it is responsible for formation of albumin and a large portion of the globulin in the blood. Urobilinogen is converted to bilirubin by the liver. Porphyrins are excreted by the liver.

Injury. Although the liver is partially protected by the lower portion of the thoracic cage, it is frequently lacerated, with resultant hemorrhage and escape of bile into the peritoneal cavity. Since the liver is a bulky organ, and somewhat friable, it is commonly damaged by blunt trauma. In a small series of 18 cases of hepatic injury studied by Musselman and associates (4), over half were sustained by blunt (nonpenetrating) trauma. In half of them fractured ribs were present.

Manifestations. Pain is fairly common, although it often is produced by rib and soft tissue injury. Occasionally it is referred to the right shoulder. Over half of the patients will be in shock when they arrive in the emergency room; the cause of this shock is hemorrhage and/or bile peritonitis, the latter being caused by the bile escaping from the severed bile ducts. Hemorrhage alone may cause the shock, but a collection of bile in the peritoneal cavity is alone enough to cause it; bile is

irritating, causing a chemical peritonitis and an exudate of plasma into the peritoneal cavity with resultant decrease in blood volume and often a drop in blood pressure. Although three fourths of the patients studied by Musselman (4) had tenderness and muscle spasms in the right upper quadrant, it must be remembered that occasionally very few local signs are present; the presence of local signs may be explained by damage to a minimal number of bile ducts and minimal soft tissue injury. Nausea and vomiting are uncommon. At times, abdominal distention and areas of dullness with or without a mass (massive blood clot) may be encountered. If the diagnosis is in doubt, aspiration of the peritoneal cavity with a syringe and needle may yield blood and reveal the diagnosis.

TREATMENT. If a laceration of the liver is suspected and the evidence of bleeding does not disappear after two or three units of blood and the lapse of a few hours, celiotomy will be indicated. If the hemorrhage (with or without the escape of bile) has been severe enough to produce shock, immediate operation is indicated (after procurement of several donors) because bleeding from the liver that has been severe enough to produce shock will rarely stop spontaneously. Moreover, even if it did stop, there is usually ample indication for operation because a tear deep enough to produce severe hemorrhage is invariably associated with severence of bile ducts of sufficient size to give rise to bile peritonitis, which so often leads to bacterial peritonitis unless the bile is removed. In the operation, the laceration should be repaired by suture. Actively bleeding vessels can usually be tied or controlled by mattress sutures in the liver; if they cannot, application of gelfoam and use of sutures extending through the liver on each side of the laceration will usually be adequate for control of bleeding. The abdomen should be explored thoroughly for evidence of other injuries requiring operative therapy. Drainage of the abdominal cavity is indicated in all severe lacerations of the liver to prevent accumulation of bile in the peritoneal cavity from postoperative leakage at the site of injury and repair.

Hepatitis. The term hepatitis is an inclusive one and comprises various types of inflammations of the liver, which may be classified roughly into those produced by chemicals and those produced by various types of infection. In many instances, however, the etiology of hepatitis, particularly the noninfectious type, is unknown.

Whether inflicted by chemicals or bacteria, the injury may be difficult to detect microscopically. Frequently, nothing more than a cloudy swelling is noted, but there is no doubt that considerable damage to the function of the cell may be sustained without revealing microscopic change. On the other hand, the damage may be so severe as to cause necrosis of the cells without producing very serious clinical manifestations. This, no doubt, happens frequently, but the remarkable power of cellular regeneration in the liver replaces the damaged cells very rapidly.

TYPES OF HEPATITIS. As already mentioned, two general groups of hepatitis are recognized: (*a*) chemical (toxic) and (*b*) bacterial (infectious). In a few cases, however, both mechanisms may play a role. It is possible also that other types of etiologic agents may be responsible in obscure cases.

(*a*) *Chemical or toxic hepatitis* is likewise known as acute hepatic necrosis, originally designated as acute yellow atrophy by Rokitansky (1842). Numerous chemicals, including arsenic, chloroform, atophan (cinchophen), sulfonamides, carbon tetrachloride, and carbon bisulphide, have been identified as etiologic agents (Fig. 3). However, on many occasions, no causative factor can be discovered and the toxic agent is probably of intrinsic origin. Various toxins formed in the intestinal tract during the process of digestion and absorption may reach the liver by way of the portal vein and exert direct damage on the parenchymal cells so that actual necrosis occurs. Early manifestations are restlessness, headache, lethargy, anorexia, and jaundice. The thymol and cephalin tests are strongly positive early in the disease. The severity of the disease is variable, but on most occasions it is fulminating with a high death rate. In the fatal cases, the lethargy is followed by stupor, coma, and death.

Cholangiolitic hepatitis is a term popularized by Watson to designate certain types of hepatitis (or cirrhosis) in which cellular damage is minimal; the damage is sustained primarily in the cholangioles. The etiology is

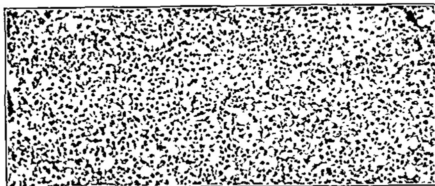


Fig. 3. Acute hepatitis with necrosis, probably of chemical origin. Note the diffuse destruction of hepatic cells with mild infiltration of lymphocytes and fat. The liver was small and yellow, and of the type described as "acute yellow atrophy." The patient, a 40-year-old woman, complained of slight abdominal pain and jaundice of three weeks' duration, and had been taking a drug almost daily for many months, for arthritis. Among other ingredients the drug contained cinchophen, a chemical noted for its toxic action on the liver.

not clear. At times, the causative factor appears to be an intrinsic toxin. On other occasions, chemicals or poisons (e.g., arsenic and thorazine) can be identified as the causative agent.

The status of hepatic function is an important feature of cholangiolitic hepatitis. The thymol and cephalin tests are usually normal and the alkaline phosphatase elevated. Jaundice is common; during the acute stage, stools are acholic. The liver is enlarged. Unfortunately, biopsy is not diagnostic. In the chronic form, the disease resembles Hanot's cirrhosis; during recent years, many clinicians have abandoned this latter term, identifying this disease as chronic cholangiolitic cirrhosis, largely because the manifestations of cases originally described by Hanot were not sufficiently consistent. This disease is a medical disease but has surgical significance because it is so difficult to differentiate from obstructive jaundice, which it resembles very closely. Fortunately, operations erroneously performed are usually tolerated fairly well since liver function is not significantly disturbed.

(*b*) *Hepatitis due to infection* may be divided into that produced by 1. viral infection; 2. pylephlebitis (via portal vein); 3. cholangitis (via bile ducts); and 4. pericholangitis (via lymphatics).

1. *Viral infection* of the liver may be of two types. Both are medical diseases but are summarized briefly here because of their importance in differential diagnosis of jaundice. The type identified as *infectious hepatitis* has an incubation period of two to six weeks; the source of infection may be food, water, milk, or infected feces. The onset is usually abrupt with fever and jaundice. It is more common in young people. The mortality is low, less than 1 per cent. *Homologous serum hepatitis* has an incubation period of 6 to 25 weeks; the source of infection is plasma, serum, whole blood, and contaminated syringes and needles. The onset is usually insidious, with little or no fever. It may occur at any age. Weakness, malaise, anorexia, and nausea are common early symptoms. Jaundice develops within a few days following onset. Stools are usually acholic in viral hepatitis for a week or two and then gradually become cholic; on rare occasions (in severe cases), the stools may be acholic for many weeks. The disease varies in intensity but its mortality rate is much higher than for infectious hepatitis. The thymol and cephalin tests are usually positive early in both types of viral hepatitis. The disease, though medical, has surgical significance because an operation is occasionally performed erroneously; if this is done in the acute stage when liver functions are seriously impaired, a fatality may result. In 5 to 15 per cent of patients with viral hepatitis the liver function tests will be normal (Capps, 5, 6). Under such circumstances, this type of hepatitis resembles acute cholangiolitic hepatitis, which has already been discussed. Neither of the two types of viral hepatitis responds to antibiotics.

2. *Pylephlebitis* or inflammation of the portal vein may develop in the vein itself or in its tributaries (Fig. 4). Complete throm-

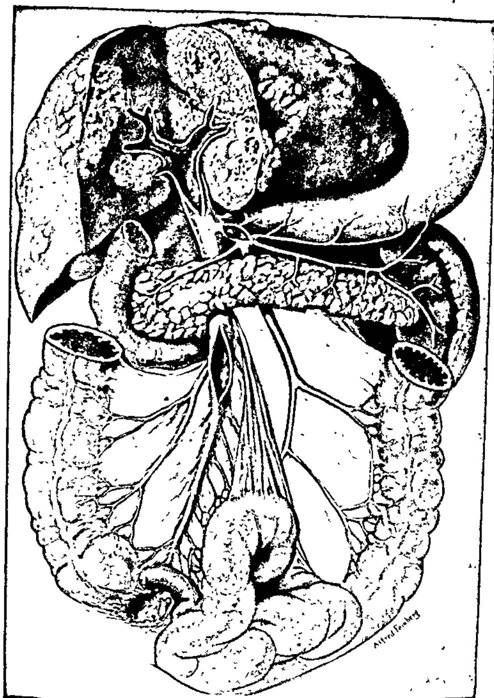


Fig. 4. Suppurative pylephlebitis arising from appendix abscess. Numerous abscesses in the liver. (From MacCallum. Textbook of Pathology, W. B. Saunders.)

bosis of the large trunk may or may not be produced. Extension into the portal tributaries within the liver takes place readily and produces serious symptoms of surgical significance. Such a condition appears usually as a complication of suppurative appendicitis, but may accompany any septic process within the peritoneal cavity. The symptoms of pylephlebitis involving a large portion of the portal system are difficult to differentiate from such complications as intraabdominal suppuration of various kinds. As stated previously, if thrombosis occurs during convalescence of a patient operated on for suppurative appendicitis, the temperature which might have been receding to normal will gradually ascend along with various symptoms, such as prostration, tachycardia, malaise, anorexia, and occasional vomiting. Jaundice may or may not be present. Chills are common. Dis-

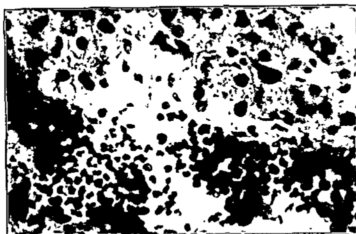


Fig. 5. Acute cholangitis from biopsy taken at laparotomy. Note the infiltration of polymorphonuclear cells; this is in the periportal area, and in reality, constitutes a miliary abscess. The patient's illness was of four weeks' duration and was manifested by high fever, jaundice and large liver with elevated diaphragm. A liver abscess was suspected and the patient operated on, but no abscess was found. For some unexplainable reason sharp improvement took place beginning a day or two following operation; the temperature dropped to normal and all symptoms subsided within a few more days.

tention with a small amount of fluid in the peritoneal cavity usually develops. The patient is obviously very ill and usually symptoms progress until death intervenes. There is a tendency for production of multiple small abscesses throughout the liver. These abscesses, along with obstruction of the portal vein and the suppurative process about the original focus, are, of course, ample cause for the fatal termination. Occasionally when the obstruction of the portal vein is complete, there may be numerous intestinal hemorrhages secondary to the portal obstruction. The production of such symptoms is readily understandable inasmuch as experimental ligation of the portal vein is often fatal due, in part, to trapping of huge quantities of blood (Elman and Cole, 7). Antibiotics are useful in preventing pylephlebitis and in controlling its effects, except that they are relatively ineffective in the treatment of the resultant liver abscesses.

3. *Cholangitis* is primarily an inflammation of the bile ducts and may be acute or chronic. The acute *suppurative* type of infection is a serious lesion, most commonly encountered in obstruction of the common duct, such as that produced by stone or by stricture. It may also be secondary to carcinoma of the head of the pancreas and ampulla of Vater, but is comparatively less common in such lesions. The infection may extend upward into the tributaries of the biliary ducts and involve the entire liver (Fig. 5). Microscopically, it may be difficult to differentiate this type of infection from pylephlebitis; multiple abscesses may likewise be formed. Edema occluding the walls of the ducts is frequently sufficient to produce biliary obstruction, thereby leading to jaundice (Fig. 6). Chills and fever, malaise, nausea, and vomiting are common manifestations. Leukocytosis is usually pronounced. Stools are acholic except when the obstruction becomes intermittent, as occurs not infrequently in patients with stones in the common duct or carcinoma of the ampulla of Vater. Treatment consists primarily of relief of the obstruction, i.e., by choledochostomy (Chart 1). If the obstruction is caused by stone, it should be removed; if caused by a malignant tumor, resection (i.e., a cancer operation) at the time of drainage for the acute suppurative process is rarely safe.

4. *Pericholangitis* is an infection or inflammation which, in most instances, is of lymphatic origin. This lesion is in reality a type of hepatitis (Graham) which, as already mentioned, arises primarily from cholecystitis but also from other infectious processes within the abdominal cavity. The liver, in such instances, is slightly swollen and the edges rounded (Fig. 7). The polynuclear and lymphocytic infiltration extends throughout the

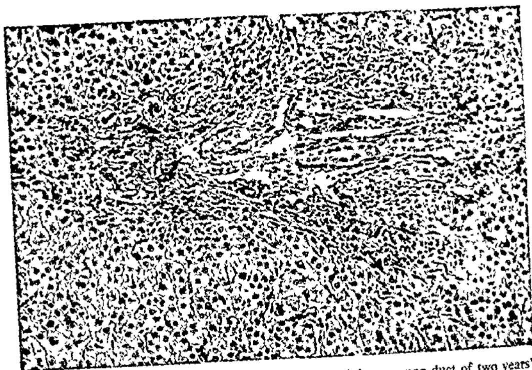


Fig. 6. Early biliary cirrhosis. The patient had a stricture of the common duct of two years' duration with alternating attacks of jaundice and freedom from obstruction. In such cases infection is constant, and, along with the biliary stasis, is an important factor in production of severe liver damage. Note the marked lymphocytic infiltration and early scar formation around the duct.

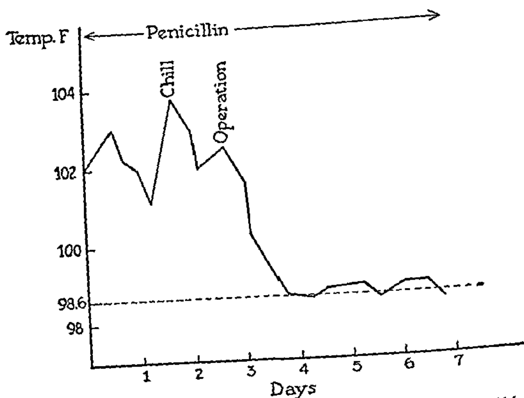


Chart 1. Suppurative cholangitis relieved by choledochostomy. Patient was a 45-year-old female who developed jaundice and severe pain in the right upper quadrant 10 days previously. She had had several lesser attacks without jaundice during the past five years. Chills and fever developed four days before entrance. Three days after admission one large stone was removed from her common duct, and a T-tube was left in for drainage. The fever subsided almost immediately. Penicillin had been of no value.

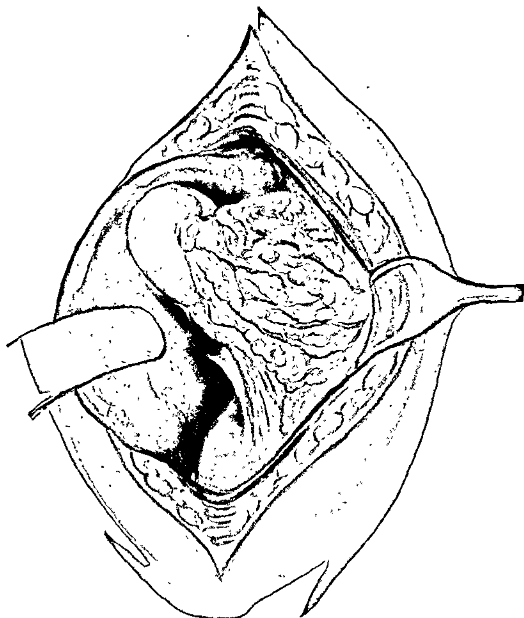


Fig. 7. Hepatitis associated with subacute cholecystitis. The rounded edge is indicative of a moderate edema. It is a common complication of cholecystitis, particularly the acute and subacute types.

portal spaces (Fig. 8). A variable amount of necrosis of adjacent hepatic cells may be present. Such processes may be secondary to acute infections not only in the gallbladder but also in the appendix, pancreas, and other organs and are associated occasionally with jaundice, fever, and so forth. Chronic pericholangitis produces very few manifestations; jaundice is usually absent. However, when the process becomes acute, all the manifestations (including jaundice) of an acute infection may be produced. Although tenderness may be quite marked over the liver, pain is usually not severe. Treatment should be directed toward the primary source of infection; antibiotics are, of course, indicated.

Clinical Manifestations of Hepatic Insufficiency. All types of hepatitis may produce hepatic insufficiency which, if severe, may in itself be lethal; impaired hepatic function occasionally develops following operations upon the biliary tract in which severe



Fig. 8. Pericholangitis produced by chronic cholecystitis; from a biopsy of the liver obtained at time of cholecystectomy. The patient had several attacks of pain in the right upper quadrant during the past several months, but no jaundice. Note the lymphocytic infiltration with beginning scar formation in the periportal area, surrounding three or four small bile ducts.

hepatitis is already present. Weakness and lassitude are usually the first symptoms complained of and become noticeable on the second or third postoperative day. The pulse rate and temperature usually remain near normal until shortly before death, but the pulse itself is soft and poorly sustained. A fall of blood pressure may accompany a collapse which simulates that due to a severe hemorrhage. Anorexia and nausea are prominent, but vomiting is unusual. Difficulty in "getting his breath" may be complained of by the patient, but there is no change in the rate or depth of respirations. Drowsiness often develops, but in the severe cases pronounced restlessness and hyperactivity may occur. Although the patient may complain of severe abdominal distress, examination of the abdomen rarely reveals anything abnormal. Jaundice is usually present. Edema of the ankles is not uncommon, and after several days the urinary output decreases alarmingly. Urobilin is found in the urine in large quantities. Severe renal damage with disturbed function may accompany acute hepatic insufficiency. The patient continues to grow weaker and more drowsy until 18 or 24 hours before death, when he is apt to become irrational. Death, which occurs near the eighth or tenth day, is preceded by coma. The term "hepatic asthenia" would appear to be appropriate when referring to patients suffering from this disease because of the debility and weakness associated with the malady. Fatalities are not uncommon in the acute insufficiency encountered in viral hepatitis and "toxic" hepatitis.

From the above discussion it will be noted that hepatic insufficiency may be of great importance surgically, particularly because it is so frequently unrecognized. Liver function tests, including particularly the thymol and cephalin tests, will be very helpful in identifying hepatic damage of this type. The alkaline phosphatase test will usually be positive (i.e., above 4 Bodansky units). This may be confusing, because a positive alkaline phosphatase test is usually indicative of ductal obstruction; however, in this case the obstruction is caused by cellular damage and edema (see also p. 660).

Treatment of Hepatic Insufficiency. Although therapy has been discussed briefly under the various types of hepatitis, a summary of therapy appears indicated because hepatic reserve is so important to the surgeon. If an obstruction to the common duct is present, it should be relieved. Fluids up to 2,500 ml. per day should be given; if the patient is unable to take fluids by mouth, this will have to be given by vein (e.g., 5 or 10 per cent glucose). An adequate carbohydrate and protein intake must be maintained (8, 9), if oral feeding is possible. The observations of Maddock and associates (10) illustrate the beneficial effect of glucose on maintenance of liver glycogen. They noted an average level

of 5.03 per cent liver glycogen in patients given supplementary glucose feedings for 12 hours previous to operation, contrasted to an average of 3.96 per cent found in normal control patients. Inasmuch as hypoalbuminemia is frequent in liver disease, repeated and large plasma and whole blood transfusions may be necessary. Obviously, an effort should be made to determine the cause of the hepatic insufficiency. Any drugs which could possibly have been a factor in the hepatic injury should be discontinued. Specific questions concerning the intake of drugs, such as thorazine, arsenic, and the like, must be asked. Abscesses should be drained, particularly if they are intraabdominal. Bed rest is necessary. Sufficient narcotics must be given to ensure adequate sleep. *If the hepatitis is of infective* origin, chemotherapy (utilizing tetracycline, streptomycin, chloromycetin, penicillin, terramycin, and so forth) should be tried.

Abscess of the Liver. Abscesses of the liver may be of two types: pyogenic, which is usually multiple, and amebic, which is usually solitary.

Pyogenic Abscess. Abscesses of this type most frequently accompany suppurative processes in the abdomen (appendicitis, and so forth) and are usually secondary to pylephlebitis or to cholangitis of the acute suppurative type. The organisms most frequently responsible for infections of this type are *E. coli*, streptococcus, and staphylococcus. The abscesses are apt to be multiple unless they happen to coalesce and form one or two large cavities. Symptoms, including weakness, malaise, anorexia, chills, and mild pain in the right upper quadrant or right shoulder, are similar to the severe manifestations of pylephlebitis and cholangitis, as already described. Ochsner and associates (11) noted nausea and vomiting, loss of weight, and jaundice in one third of the series reported by them. Intermittent fever and slight elevation of the diaphragm with lack of movement during respiration are usually the most objec*tive diagnostic signs (Fig. 9). Differentiation* from subphrenic abscess may be difficult or impossible when a large single abscess is present. Leukocytosis is pronounced and usually *higher than that noted in amebic abscesses.* The *treatment* of these abscesses may be operative (Chart 2); but they are not so amenable to drainage, chiefly because of the fact that they are usually multiple. The mortality is therefore high; however, when there are but one or two large abscesses, treatment is more hopeful. Drainage should be established



Fig. 9. Pyogenic abscess of the liver; roentgenogram showing marked elevation of the right diaphragm, which was also immobile. Operation was performed for drainage by resection of the ninth rib in the posterior axillary line; about 300 ml. of foul-smelling pus was evacuated. Recovery was uneventful (see Chart 2).

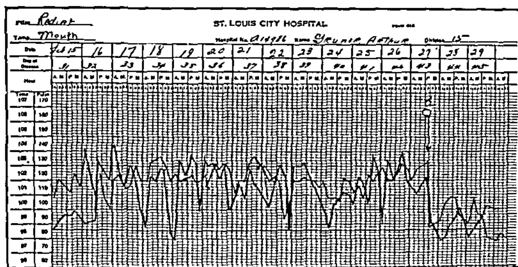


Chart 2. Temperature chart of pyogenic abscess of liver shown in Fig. 9. The patient, aged 37, was first operated on one month previously for drainage of a large intra-abdominal abscess, presumably of appendiceal origin. The abdominal and general conditions gradually improved and the temperature returned to normal. Four weeks after admission, the fever recurred (as noted above on the second day of the chart) and assumed a swinging septic form. 12 days later, as indicated on the chart, operation was performed. Following drainage of the hepatic abscess the temperature returned to normal. Recovery was uneventful.

if possible, but in such a way that the pleural and peritoneal cavities are not contaminated; the retroperitoneal approach (Ochsner) should be utilized whenever possible. Penicillin and streptomycin or some other antibiotics (depending upon sensitivity tests, if a culture is available) should be given.

Amebic Abscess. Years ago, amebic abscess of the liver was thought to be a tropical disease but it is well known now that it is encountered in the temperate as well as tropical climate. As the name implies, the causative organism is the *Endameba histolytica*. The lesion is much more common in males than females. The relationship of the development of the abscess to the initial intestinal infection is extremely variable. Furthermore, a history of diarrhea may be absent. In a series of 741 collected cases (including their own), Ochsner and DeBakey (12) noted a history of diarrhea in only 58 per cent of cases and diarrhea at time of entry in only 21 per cent of the cases. The symptoms of amebic abscess are fever, weakness, malaise, and mild pain in the epigastrium, right upper quadrant, and right shoulder. Fever is apt to be of the remitting type, accompanied by sweating and exhaustion; loss of weight is common. Examination may reveal nothing more specific than a mild degree of tenderness over the liver (Fig. 10). However, as the abscess increases in size the area of hepatic dullness likewise increases. The diaphragm may be elevated, and upon fluoroscopic examination is usually found to be immobile. Perforation of the diaphragm may occur, with the production of an empyema. More rarely, the pus breaks through the lung into a bronchus, producing a bronchial fistula. The pus found in an abscess of the liver is characteristically of a brick red color. The amebas are found in the pus in only about 30 per cent of cases (DeBakey and Ochsner, 13), but more often from the wall of the cavity.

The treatment is largely medical. Rogers (14) was perhaps the first to demonstrate the truth of this statement; he noted a decrease in mortality from 56 per cent after open drainage to 14 per cent after conservative treatment, including closed drainage (aspiration) and medicinal therapy. Rogers attributed the high mortality following open drainage to secondary infection of an abscess cavity which was initially sterile. Occasionally, spontaneous secondary infection develops; if microorganisms are found in the pus, open drainage is usually indicated. The drug most commonly used is chloroquine, in doses of 0.6 gm. by mouth daily for two or three

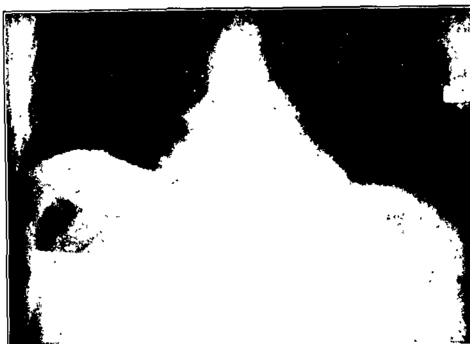


Fig. 10. Amebic abscess of the liver. The patient, a 45-year-old male, complained of loss of weight and strength; examination revealed an intermittent fever and a palpably enlarged liver. The roentgenogram was taken in the upright position after part of the aspirated pus had been replaced by air; note the fluid level. Emetine was injected into the cavity; it was also given by mouth. Recovery was uneventful without operation. (St. Louis City Hospital.)

days followed by 0.3 gm. daily for two or three weeks. Emetine and diodoquin are also used, but the former cannot be used longer than 10 days with safety. Irrigation of the abscess cavity is not desirable, although it may have to be aspirated more than once (Ochsner, 15). In the New Orleans series, Ochsner reports that the mortality rate has now dropped to 3.2 per cent. Seldom do patients with amebic hepatitis (without abscess) die, and seldom indeed do patients with multiple abscesses survive. Empyema caused by perforation through the diaphragm may be treated by aspiration, but if culture reveals pyogenic organisms, surgical drainage will be indicated.

Jaundice. To understand the mechanism of production, and the signficance of jaundice, it is necessary that the chief factors in the metabolism of bile pigments be understood. Bilirubin is present in the blood normally in quantities equal to 0.1 to 0.4 mg. per 100 ml. of serum (quantitative Van den Bergh). When the content rises to 2.0 or 2.5 mg. per 100 ml. of serum, macroscopic jaundice results. Levels above 0.2 mg. are abnormal for the one-minute test for bilirubin. Latent jaundice may be defined as hyperbilirubinemia without visible jaundice. Bilirubin is made by the reticuloendothelial system, e.g., the bone marrow, lymph nodes, spleen, and the Kupffer cells of the liver, but is normally excreted only by the liver. Bilirubin is formed from hemoglobin, probably through the intermediary product hematin. After bilirubin is excreted with the bile into the intestine, the action of the bacteria converts it into urobilin which is absorbed and reconverted, in part at least, into bilirubin, chiefly in the liver. Urobilin is found normally in human bile and in traces in the urine. The stools, however, contain large amounts. Urobilin may be found in the urine in certain diseases. It is assumed that in such instances a slight degree of hepatic insufficiency exists to the extent that the urobilin cannot be converted into bilirubin, and is therefore excreted by the kidney. In other instances, urobilinuria occurs when the liver, though normal, is unable to remove the urobilin from the blood stream when produced in excess by such conditions as hemolysis. On the other hand,

when no bile reaches the intestine, as in complete obstructive jaundice, urobilin disappears from the urine.

Jaundice first appears in the scleras and conjunctivas and gradually becomes noticeable over the skin and mucous membranes throughout the rest of the body. When severe jaundice has been present for a long time the skin turns to a dark greenish bronze color because of the transformation of bilirubin to biliverdin.

For obvious reasons, it may frequently be of considerable advantage, from the surgical as well as medical standpoint, to determine the intensity of jaundice and to follow its course with reference to a decrease or increase. As stated previously, jaundice is dependent upon the amount of bilirubin in the blood. There are several methods of estimating the bilirubin content of the blood; the quantitative Van den Bergh test (or a modification) is the one most commonly used. It is much more accurate than the icterus index test, which is no longer popular because of its inaccuracy.

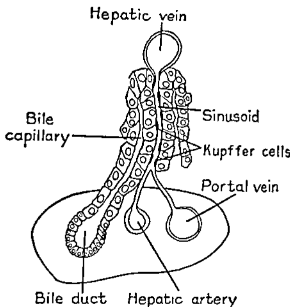


Fig. 11. Diagram to illustrate the mechanism of obstructive jaundice. If the bile duct becomes obstructed, the bile obviously is blocked from its normal exit and "spills" over into the sinusoid, which empties into the hepatic vein; the bile thereby gains access to the general circulation. The manner in which the capillaries of the portal vein and hepatic artery unite to form the sinusoid is not clearly understood and is illustrated in a diagrammatic fashion. (Modified from McNee. Quart. J. Med.)

TYPES OF JAUNDICE. Aside from hemolytic jaundice, which is really a disease of the spleen and hematopoietic system and not of the biliary apparatus, jaundice is due to the failure of bile to reach the intestine. Because bile is constantly formed, this failure obviously results in the accumulation of bile in all the tissues of the body and in the blood, as already mentioned. There are a variety of diseases which result in a failure of bile to reach the duodenum; these can be conveniently divided into two general groups, *hepatogenous* and *extrahepatic* (Fig. 11), each of which is described later in more detail. In hepatogenous jaundice the liver parenchyma itself is diseased so that it cannot excrete bile; such lesions include acute hepatic necrosis, the two types of viral hepatitis, and cirrhosis. In extra hepatic jaundice the disease is in the biliary ducts which become obstructed by one lesion or another, usually either stone or tumor; this type is therefore called obstructive jaundice. Hepatogenous jaundice is, in general, a medical disease; surgery has little to offer aside from the value of laparotomy in making the diagnosis and excluding obstructive jaundice. Obstructive jaundice, on the other hand, is a surgical disease because operation often permits relief of the obstruction or even cure of the lesion producing it. The importance of both types of jaundice to the surgeon is that the clinical differentiation is sometimes difficult or impossible to make, thus justifying an operation for such a purpose.

Regardless of the cause of the jaundice, it is important to recognize the existence of any damage to the liver parenchyma for reasons to be discussed later. For this purpose, the patient's symptoms may be of value but *tests of hepatic function* are often more informative. Of the many tests which have been devised, the thymol turbidity test, the cephalin test, the alkaline phosphatase test, the urobilinogen test, reversal of the plasma albumin and globulin ratio, and the bromsulphalein test are the most important. The latter test is a sensitive liver function test, but is not very accurate in the presence of jaundice. On the basis of the results of these tests, it is usually possible to differentiate extrahepatic types of jaundice from hepatogenous jaundice, as will be discussed later. Regardless of

the absence or presence of infection, the retention of bile salts alone, if continued long enough, will eventually produce hepatic damage and actual necrosis of many of the cells. The liver then will become enlarged and a mild edema as well as a lymphocytic infiltration will take place. Ultimately, scar tissue will be deposited and an actual microscopic biliary cirrhosis will be produced.

In all types of jaundice, bile pigment is found promptly in the urine but does not appear in the tissues until the serum attains a certain concentration, i.e., 2.0 to 2.5 mg. per cent; only when values above this level are reached is clinical appearance of jaundice evident. Because of this latent period in the clinical appearance of jaundice the determination of the amount of bilirubin in the blood may be a valuable method of identifying occult or latent jaundice and also in following the variations in the degree of jaundice.

Postoperative hemorrhage in jaundice is a more serious and not infrequent complication; it may occur at any time during the first 10 postoperative days but perhaps most commonly between the fourth and the sixth day. Hemorrhage occurs because blood clotting is defective due to the deficiency in the prothrombin content of the blood (Dam, 1935). Although the bleeding and clotting time is usually normal, the clot is defective or fragile because of the diminution in the conversion of fibrinogen to fibrin. This is an indirect result of the prothrombin deficiency (hypoprothrombinemia) which, in turn, is due to a lack of vitamin K. This vitamin is fat soluble and therefore requires the presence of bile salts in the intestines for its assimilation; however, a water soluble synthetic product having vitamin K activity is available for parenteral use. A deficiency follows complete jaundice and also complete external biliary fistula because of the absence of bile in the intestinal tract, thereby preventing absorption of the vitamin from the food. Details of jaundice may be found in publications elsewhere (1, 16, 17).

1. *Hepatogenous Jaundice.* In this group, the disease is primary in the liver, producing so much cellular damage that bile is not being excreted into the ducts which are, indeed, normal grossly and microscopically; at times, edema or fibrous tissue about the bile ducts may be sufficient to exert an additional intrahepatic obstructive mechanism. Hepatogenous jaundice comprises a great variety of conditions; some of them are called infective or toxic jaundice (acute hepatic necrosis), but the cause in many cases is really unknown. The simplest type is virus hepatitis, which is the most common single type of jaundice and has already been discussed. Acute hepatic necrosis may be caused by various chemicals (see p. 660) or endogenous toxins. Of recent years thorazine is a common cause. The appearance of the liver varies considerably, depending upon the type of disease present. In acute hepatic necrosis, the liver is small and presents a striking yellow color. In patients having hepatitis due to infection, the liver is moderately enlarged and swollen, with rounded edges. In cholangiolytic jaundice, the liver is large and, as the disease advances, becomes cirrhotic. The gallbladder and common duct are normal. Enlarged lymph nodes are commonly found at the hepatic hilus. Allied to the examples of primary liver disease discussed above are patients with various types of cirrhosis. Cirrhosis, when it produces jaundice, must be considered in this group, even though the large amount of scar present in the liver may produce a variable degree of duct obstruction. In many instances ascites may also be present, which helps considerably in the differential diagnosis because ascites, though occasionally present in other types of hepatogenous jaundice, is rare in obstructive jaundice except when caused by peritoneal metastases.

The surgical problem in hepatogenous jaundice is largely a diagnostic one, i.e., differentiation from extrahepatic jaundice for which surgery has much to offer. Liver function tests are valuable in differentiating hepatogenous from obstructive jaundice since they are usually positive in the former and negative in the latter. The thymol turbidity test is one of the most valuable since it is usually extremely sensitive. It must be remembered, however, that in patients with prolonged obstructive jaundice, liver function tests may be positive, particularly if infection is present. Only rarely will it be impossible to differentiate the two lesions

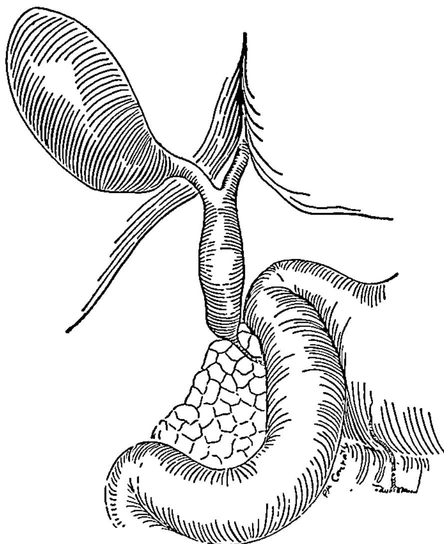


Fig. 12. Diagram to illustrate one of the types of obstructive jaundice. The duodenum has been rolled back to expose the pancreas. In this instance the common duct is distended because of compression of the terminal end of the common duct by the pancreas. The pathologic process in the pancreas capable of producing this compression may be either carcinoma or pancreatitis. In obstruction of this type (absence of infection in the biliary system) the gallbladder is distended, fulfilling part of the requisites of Courvoisier's law (see text).

without operation. It is the possibility that the patient has a stone or a carcinoma for which surgery offers the only hope of relief or cure that often tips the balance in favor of laparotomy.

2. *Obstructive Jaundice.* Obstructive jaundice may be extrinsic or intrinsic. The most common of the former type is carcinoma of the pancreas, which is discussed in Chapter 29. The most common of the intrinsic type is stone in the common duct, which is discussed later in this chapter. In carcinoma of the pancreas (Fig. 12), the manifestations are apt to develop insidiously, pain being present in no more than 20 per cent. When stones in the common duct are the cause of the obstruction, pain will be present in fully 80 per cent of cases; these attacks, including the jaundice and acholic stools are apt to be intermittent, in contrast to carcinoma of the pancreas in which the jaundice and acholic stools are apt to be permanent, once they develop.

Other noninflammatory or aseptic obstructive lesions include carcinoma of the liver, carcinoma of the common duct, congenital strictures, cystic dilatations of the common duct, and other neoplasms which compress the ducts from without. It should be emphasized that certain types of hepatitis,

particularly cholangiolitic hepatitis, are associated with biliary obstruction, primairly in the smaller intrahepatic bile ducts. In "toxic" hepatic or acute hepatic necrosis, the edema within the liver may likewise produce obstruction to the intrahepatic ducts.

Contrary to general opinion, jaundice due to obstruction alone may exist for some time without producing significant damage to the liver. This is particularly true in the slowly developing jaundice which follows an obstruction by carcinoma at the head of the pancreas. However, if there is an accompanying infection, as for example, in the presence of stones in the common duct, there is very obvious and often severe damage inflicted upon the hepatic parenchyma as will be demonstrable by liver biopsy. In chronic obstruction, the liver may become cirrhotic (biliary cirrhosis) giving rise ultimately to severe hepatic insufficiency.

3. *Hemolytic Jaundice*. Jaundice of the hemolytic type has much more relation to the spleen than to the liver. Splenomegalia is fairly consistent. Splenectomy in selected cases is curative. The role of the liver in this disease is limited for the most part to the fact that the amount of bilirubin converted from the hemoglobin (due to excessive destruction of erythrocytes) is so great that the liver is unable to excrete it in a normal fashion. The bilirubin accumulates in the blood stream, resulting in jaundice. The condition is therefore discussed under diseases of the spleen.

DIFFERENTIAL DIAGNOSIS IN JAUNDICE. It is extremely important to differentiate hepatogenous from extrahepatic obstructive jaundice because, in general, the therapy in the former is nonoperative whereas in the latter it is surgical. In general, hepatogenous jaundice is painless in about 80 per cent of cases, whereas obstruction by stone produces pain in about 80 per cent of cases. Pain is usually absent in carcinoma of the head of the pancreas, but epigastric distress of the dyspeptic type is common. (Pain is common, and in fact almost constant, in carcinoma of the body of the pancreas.) The most severe pain of all the groups is encountered in patients with stones in the common duct. The presence of chills may be helpful since they are rarely encountered except in patients with common duct stones, with traumatic strictures, occasionally in obstruction due to carcinoma of the pancreas, or with septicemia accompanying serious sepsis, such as pneumonia.

The age of the patient will frequently be very helpful, since viral hepatitis, which is no doubt the commonest type of hepatogenous jaundice, is usually encountered in young adults, whereas stones in the common duct and carcinoma are usually encountered in later adult life. Sex will be of only slight value in differentiation (Table 1).

The onset of the disease may be very helpful; it is usually acute with severe pain in common duct stone, but in viral hepatitis and carcinoma of the head of the pancreas it is apt to be insidious. Pain occurs in cancer of the head of the pancreas but is rarely severe. The course of the disease frequently establishes the diagnosis with certainty, i.e., allows the surgeon to arrive at the correct decision as to whether or not operation is indicated. For example, if the patient's history reveals a rather sudden onset of relatively painless jaundice, and during two or three weeks' observation shows decrease in symptoms, including a lowered bilirubinemia and more pigment in the stool, the decision to refrain from operative interference will rarely be erroneous on the basis that the jaundice is hepatogenous in origin. In many types of hepatogenous jaundice, the spleen will be enlarged; in obstructive jaundice, it rarely will be enlarged. The size of the liver will not be of much diagnostic assistance, since it will be moderately enlarged in both types of jaundice, though markedly enlarged in most patients with cholangiolytic jaundice. Marked enlargement of the liver is practically never seen in obstructive jaundice due to stone unless a liver abscess is present.

Jaundice tends to be more intense in hepatogenous jaundice than in jaundice due to stones in the common duct. In the former, the color of the stool is variable though usually lighter than normal. In viral hepatitis, the stools are usually acholic for a week or two and then become cholic. In jaundice due to stones in the common duct, acholic stools as well as the jaundice are apt to be intermittent. In carcinoma of the pancreas, bile rarely is found in the stool once it is noted to be absent. *Stool examinations* may therefore be of great value in making a differential

TABLE 1. Important Factors in Differential Diagnosis of Jaundice

It should be emphasized that the features listed represent average data and must not be interpreted dogmatically.

	Extrahepatic Jaundice		Hepatogenous Jaundice	Splenogenous Jaundice
	Stone in Common Duct	Carcinoma of Head of Pancreas	(Toxic* or Infective Hepatitis)	(Hemolytic Icterus)
Age	Usually over 40	Usually over 50	Any age; more frequently young	Variable; may be since birth
Sex	Females predominant	Males predominant	Either	Either
Character of Onset	Sudden	Insidious	Moderate	Variable
Previous Attack	Usually	No	Rarely	Remissions
Pain	Severe and usually colicky; present in over 80%	Pain (usually mild) in about 20%; fairly constant if tumor in body	Rare and mild	None
Degree of Jaundice	Mild to intense, often intermittent	Moderately intense early, usually progressively deepens	Severe, but varies and may be intermittent	Varies
Pruritis	Usually present	Usually present	Absent, usually	Absent
Stool	Intermittently acholic	Acholic and permanent	Acholic for few days only	More pigment than normal
Size of Gallbladder	Usually normal size, but diseased	Always dilated except rarely when gallstones also present	Normal	Normal
Liver Function Tests	Variable to positive	Normal, except serum phosphatase elevated	Strongly positive	Normal
Plasma albumin	Normal to reduced	No change	Low	Occasionally significant
Fever	Intermittent but not common, may have chills	No, except occasionally suppurative cholangitis	May be present early, but variable	None except in severe crises
Serum Amylase	Occasionally elevated day or two following obstruction	Elevated early in disease Serum lipase may be elevated	Normal	Normal
Size of Liver	Variable	Enlarged late in course of jaundice	Usually enlarged	Variable
Blood	Mild to marked leukocytosis at times	Anemia later	Anemia if jaundice is severe and persistent	Spherocytes; anemia in crises
Size of Spleen	Normal	Normal	Occasionally enlarged	Large
Miscellaneous Tests or Data	Stones on x-ray in 20 to 40%		May occur in epidemics	Increase fragility of RBC; Spherocytes; stools hypercholic; no increase pigment in urine

* Cholangiolytic hepatitis, usually associated with jaundice, is probably of toxic origin. It differs from most types of toxic hepatitis in that liver function tests are usually normal.

diagnosis. Urobilin will be present in the urine of patients with hepatogenous jaundice but rarely in patients with complete obstructive jaundice. Pruritis is much more common in obstructive jaundice than in hepatogenous jaundice.

Tests of hepatic function may be extremely helpful, although it should be stated that many clinicians believe their importance has been exaggerated. The *thymol turbidity* test is valuable in differential diagnosis because it tends to be positive (i.e., above 4 units) in hepatogenous jaundice and negative in obstructive jaundice. A positive test depends on an elevation of gamma globulin. It is perhaps the most sensitive test we have for hepatocellular (intrahepatic) jaundice. The *cephalin flocculation* test is also of value in differentiation between the two types of jaundice. Flocculation is negative or 1+ in extrahepatic jaundice and 4+ in intrahepatic jaundice. The *serum alkaline phosphatase* test is elevated (above 10 Bodansky units) in patients with extrahepatic obstruction, due to interference with its excretion. However, it is often elevated in hepatogenous jaundice; this is probably due to obstruction within the liver due to compression of ducts by edema or fibrosis. In severe hepatic damage, *vitamin K* is apt not to restore a low prothrombin time to normal as it will in jaundice with little hepatic damage. A *reversal or a tendency toward reversal in the albumin globulin ratio* is a sign of liver disease, but is not an early test. It usually requires chronic hepatic insufficiency to produce a definite reversal. The *urobilinogen* test is a particularly sensitive test of liver function because this pigment disappears from the urine in complete biliary suppression, i.e., when bile is absent from the intestinal tract. Urobilinuria therefore indicates definite but not complete impairment of bile excretion. The level of *cholesterol esters* may be reduced in hepatocellular disease because esterification of cholesterol is diminished early in hepatic disease; however, low readings are often found in patients who do not appear to have significant hepatic disease (16). The *bromsulphalein* test is very reliable but will not give accurate readings in the presence of jaundice. Ordinarily, a retention is not noted in hepatocellular disease but is fairly constantly elevated in patients with cirrhosis or carcinoma of the liver. Apparently this test is influenced by the blood supply to the liver insofar as there is retention when obstruction to blood flow in the liver is present. Recently the level of *transaminase* in the serum has been utilized as a test of hepatic function (18) since it is high in the acute stage of viral hepatitis and in other patients with obvious severe insufficiency. However, it is also high in acute myocardial infarction and certain other acute serious diseases. The value of liver function tests in surgical diagnosis has been discussed in detail by Hunter (18a).

TREATMENT OF JAUNDICE. Obviously, the first requirement in the treatment of jaundice is to determine and remove the cause. This may require extensive study, including a large amount of laboratory data. Frequently it is extremely difficult to determine the exact cause of the jaundice. On such occasions, exploratory laparotomy may be indicated on the assumption that a lesion will be found which can be effectively treated surgically. If the jaundice is produced by mechanical obstruction, particularly if extrahepatic (e.g., stone), operation is obviously indicated for its correction. On the other hand, if the jaundice is hepatogenous, e.g., due to a diffuse damage or infection of the liver alone (acute hepatic necrosis, viral hepatitis, and so forth), operation will be therapeutically useless and harmful. Operation in patients with acute viral hepatitis may actually be fatal. However, such patients usually have strongly positive liver function tests (thymol and cephalin), making the diagnosis definite. The patients having hepatogenous jaundice of the type difficult to differentiate from extrahepatic type are usually not harmed by celiotomy, because liver function tests are normal or near normal; cholangiolytic jaundice is an example.

Treatment consists of a high carbohydrate intake and an adequate protein intake (8); however, it must be remembered that an excessively high protein intake in severe liver disease may be very harmful (producing nitrogen retention and the like). If oral feedings are impossible, intravenous feedings with glucose and perhaps a moderate amount of amino acids are indicated. Transfusions should be given to bring the hematocrit levels

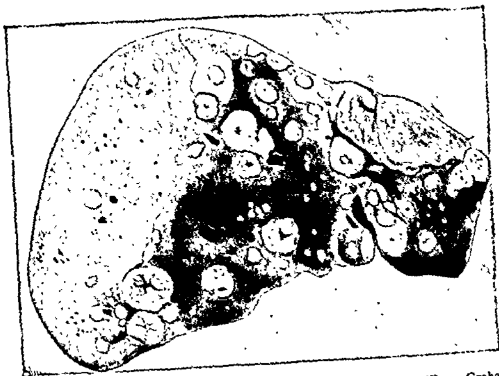


Fig. 13. Metastatic adenocarcinoma, liver, from a carcinoma of the breast. (From Graham. Surgical Diagnosis, W. B. Saunders.)

up to normal. One of the synthetic products, such as 2-methyl-1,4 naphthoquinone or 4-amino-2-methyl-naphthol, with vitamin K activity should be given. Each of these two drugs is given in doses of 5 to 50 mg. per day. The latter drug is soluble in water and the former likewise soluble if combined with sodium bisulphite (hykinone); thus either may be given subcutaneously or intrave- nously. In severe hepatic disease, these com- pounds will not relieve hypoprothrombine- mia; repeated transfusions should then be given.

Neoplasms. The liver is frequently the site of tumors, especially of a malignant type, secondary to a primary focus elsewhere (Fig. 13). Carcinoma of the stomach, intestine, and other intraabdominal organs tend to metastasize first to the liver. Fortunately for the patient, such metastases rarely produce many symptoms other than mild discomfort and tenderness, although the liver on some occasions becomes greatly enlarged. If the metastatic nodules are sufficiently numer- ous, jaundice may be produced. Increasing dyspepsia, weakness, loss of weight, and other systemic manifestations of malignant disease will develop as the disease progresses.

On rare occasions, carcinoma may be pri- mary in the liver, arising in most instances in the bile ducts. It sometimes occurs also in association with or as a complication of atrophic cirrhosis. The clinical manifesta- tions are no different from those encountered in metastatic carcinoma in the liver. At- tempts should be made to arrive at a diag- nosis as early as possible because on rare occasions excision of the tumor in the liver may be possible. Actually the entire lobe (right or left) can be removed (19), but is done only if there is no evidence of disease in the other lobe or elsewhere.

Miscellaneous Diseases of the Liver. The liver may be afflicted with various types of *cirrhosis*, the most important of which surgi- cally is the atrophic (Laënnec) type. When cirrhosis has progressed to the point where the portal circulation has been obstructed sufficiently to produce an ascites, surgical relief may be attempted. Such procedures as implantation of the omentum in the abdomi- nal wall (omentopexy) with scarification of the liver, diaphragm, and spleen were origi- nally used in the treatment of portal hyper- tension caused by cirrhosis, but are not very effective. This procedure has been sup- planted by portacaval shunt (20), spleno- renal shunt, and resection of the terminal end



Fig. 14. Drawing of echinococcus cyst of the liver from sketch made at the time of operation. The gallbladder was normal; its dome may be identified to right of the cyst. The symptoms consist of mild pain in the right upper quadrant of three years' duration and simulated cholecystitis. The cyst was evacuated at the time of operation and drained; the fluid contained hundreds of daughter cysts of variable size. The wound healed after several weeks. Patient was alive and well when last seen, seven years after operation.

of the esophagus as discussed on page 716.

Echinococcus cysts, although rare in this country, occur more frequently in the liver than in other organs. They are apt to develop insidiously, with only a moderate amount of discomfort and pain in the upper abdomen. Examination usually reveals a large liver because of the development of the cyst (Fig. 14). Excision should be performed if possible, but if not feasible, evacuation of the cyst by operative procedures is usually successful in eradicating the disease (see p. 126).

GALLBLADDER

The gallbladder is a pear-shaped organ located *in a fossa on the inferior surface* of the liver between the right and quadrate lobes. The neck of the gallbladder terminates in the cystic duct which empties into the hepatic duct, thus forming the common hepatic duct (Fig. 15). Its blood supply is derived from the cystic artery, which is derived from the right branch of the hepatic artery.

Inflammation of the gallbladder (cholecystitis) and stones within the organ (cholelithiasis) are common diseases and occur with such varied manifestations that they are worthy of special attention. The gallbladder has definite functions, but it is not necessary to life.

The normal gallbladder acts largely as a storehouse for bile, which accumlates within its lumen because of the resistance of the sphincter of Oddi and the relaxation of the gallbladder which occurs between meals.

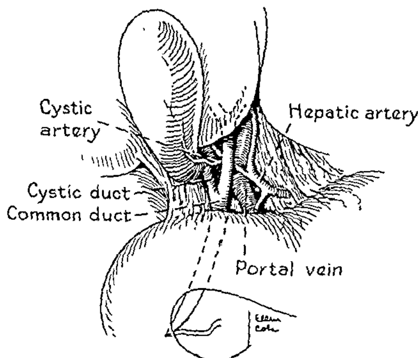


Fig. 15. Anatomy of the gallbladder and bile ducts. The two intrahepatic ducts join in 90 per cent of cases before they leave the liver; on the contrary the portal vein divides in 90 per cent of cases before it enters the liver. Note that the posterior portion of the common duct usually lies in contact with the right branch of the hepatic artery and the portal vein.

Large amounts of bile are thus stored in spite of the small size of the viscus because the normal gallbladder mucosa absorbs water and thereby concentrates the constituents of the bile (Rous and McMaster, 1921). At mealtime and during the process of digestion the musculature of the gallbladder, aided perhaps by breathing, intraabdominal pressure, and so forth, causes expulsion of bile through the relaxed sphincter. Removal of the gallbladder causes dilatation of the extrahepatic ducts (Judd and Mann, 21) and a slight dilatation of the intrahepatic ducts (Counsellor and McIndoe, 22).

Infection is known to be important in the *pathogenesis* of cholecystitis but the inflammation is usually nonbacterial, particularly at its onset. Andrews (23) has called attention to the importance of an increase in bile salts in the bile, in the development of chemical cholecystitis which has been corroborated by Womack and Bricker (24). Likewise Wolfer (1931) has shown that reflux of pancreatic juice into the gallbladder by way of the common duct may instigate cholecystitis. Chronic obstruction of the cystic duct (Fig. 16) may initiate this inflammation because of resultant overconcentration of bile, and the like (Cole and associates, 25); in their experiments, infection was superimposed in 30 per cent of cases, representing about the same incidence of positive culture noted in human cholecystitis. The ability to find bacteria in only a portion of diseased gallbladders has led many observers to doubt that the inflammation is bacterial in origin, particularly at the onset. Therefore it seems possible that, at least on many occasions, the presence of infection may be explained as being superimposed on the initial inflammation as it is in animal experiments. The fact that cholecystectomy can be performed in early acute cholecystitis with almost complete absence of infective reactions likewise supports this view that the initial inflammation may frequently be chemical and the bacterial infection superimposed later. In 100 cases, Illingworth (26) noted that of 62 positive cultures obtained from the wall of the gallbladder, 34 were *Streptococci* and 17 were *Bacillus coli* (*E. coli*). On the other hand, of the 40 instances of positive culture from the bile in the 100 cases, 16 were *Streptococci* and 20 were *Bacillus coli*.

There are four chief ways in which bacteria may reach the gallbladder: *1. hema-*

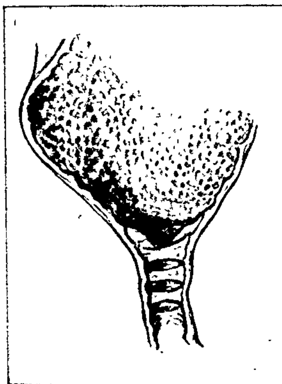






Fig. 16. Partial obstruction of the cystic duct. The transverse bands in the cystic duct of the three gallbladders shown above and to the left represent anomalies (of the valves of Heister) and inflammatory lesions which can partially obstruct the duct. The two photographs and the drawing were made from specimens removed by operation. All three patients had pain in the R.U.Q. typical for chronic cholecystitis. The two gallbladders above concentrated telepaque normally, but the one below did not. Cholecystectomy relieved the pain in all three patients. Lesions of this type are often the important factor in production of cholecystitis (see text).

togenous; 2. lymphogenous; 3. spreading infection from a contiguous organ; and 4. hepatogenous by way of the bile. Of these four methods of development of cholecystitis, the lymphogenous route would appear to be the most important. Years ago (1918), Graham and associates called attention to this mechanism of transmission of infection. Due to the rich anastomosis of the lymphatic vessels between the gallbladder and liver, spread of infection from one organ to the other, and vice versa, is no doubt a common occurrence. On some occasions, the infection perhaps breaks through the mucosal barrier of the intestine and is carried to the liver by the lymphatics or blood stream, particularly

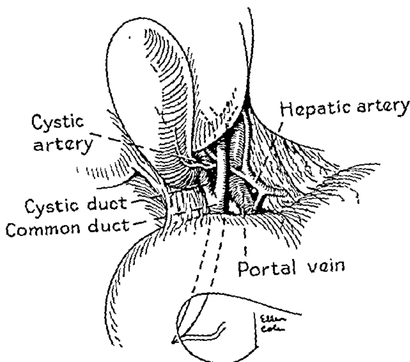


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ish color of the contents fades to a gray or grayish brown, due to absorption of the pigment or to bacterial action on it. Empyema of the gallbladder is usually associated with cholelithiasis; it requires operative correction (usually cholecystectomy). The inflammation at the onset of acute cholecystitis may be infectious but more frequently is chemical in origin, infection being superimposed later.

In most instances, acute cholecystitis subsides spontaneously, but occasionally gangrenous or necrotic areas may form in the wall of the gallbladder, thereby leading to *perforation of the organ. Perforation into* the free abdominal cavity is uncommon, but when it occurs is very serious because of the bile peritonitis which inevitably follows. Unless operation is performed within a few hours, fatality is to be expected. The omentum or contiguous organs are usually plastered against the gallbladder in such a way that perforation does not occur into the peritoneal cavity, but rather forms a pericholecystic abscess. On rare occasions, perforation may occur into the liver, the duodenum, the colon, or through the anterior abdominal wall.

Clinical Manifestations. The onset of symptoms in acute cholecystitis is usually sudden, consisting primarily of pain in the right upper quadrant, nausea, and vomiting. Fever soon follows these symptoms, as do other systemic manifestations of severe inflammatory processes, such as tachycardia, malaise, and weakness. Not infrequently there is a history of a chill at the onset. Frequently the pain, which is usually severe, radiates backward to the tip of the scapula. Deep respiration may be painful. Palpation will reveal tenderness and muscle spasm localized over the right upper quadrant, persisting for several days, depending upon the intensity of the attack. The gallbladder will frequently be palpable as a tender mass even in the face of muscle spasm over it. Jaundice induced either by a coincidental obstruction of the common duct or by hepatitis associated with the cholecystitis (Graham) may be present. The leukocyte count is sharply elevated, frequently reaching 25,000 or higher. The acute symptoms, including nausea, vomiting, and severe pain are apt to diminish sharply after the first 24 hours, whereas local muscle spasm and tenderness are more likely to persist. If perforation of the gallbladder occurs, a local abscess is usually formed and the local findings, including tenderness, pain, and muscle spasm, will be much more pronounced.

The disease is perhaps encountered more frequently in a mild form with pain of less intensity and duration (two or three days) and accompanied by only slight fever. Such attacks commonly masquerade as acute dyspepsia or indigestion. It is difficut to decide whether such attacks should be classified as *acute cholecystitis* or *exacerbations* of chronic cholecystitis. Glenn (27) has emphasized the fact that stones are encountered in the common duct in at least 5 per cent of patients with acute cholecystitis.

Differential Diagnosis. The location of the pain and tenderness in the right upper quadrant, combined with the characteristics of the pain which is usually severe and sometimes cramplike in nature, will usually point to the correct diagnosis. Occasionally, it may be confused with acute appendicitis when the appendix is retrocecal and high, but rarely does the tenderness of appendicitis localize itself so definitely in the right upper quadrant. Acute appendicitis is usually a disease of young people, whereas cholecystitis usually occurs in later adult life. Acute cholecystitis may be confused with perforated peptic ulcer, but the onset of the pain, and so forth, in the latter condition is apt to be more sudden and associated with prostration and more generalized abdominal rigidity. Moreover, in perforated ulcer there may be a history of dyspepsia relieved temporarily by food or alkali. X-ray of the abdomen with the patient in a sitting position will rarely fail to reveal air under the diaphragm if a free perforation of an ulcer is present. Frequently, the pain produced by acute pancreatitis is indistinguishable from that of acute cholecystitis but is usually confined to the midline in the epigastrium or to the left upper quadrant. Patients with acute cholecystitis are apt to have a history of previous attacks of a similar character. The pain of acute cholecystitis is similar to renal colic except that the pain in the latter instance is apt to radiate downward, even into the thigh or



Fig. 17. Subacute cholecystitis. Note the enormously thickened wall and the beginning perforation in the fundus. A large stone was present in the neck of the gallbladder.

the latter. It is apparent that a vicious circle may be established by an infection between the gallbladder and liver because of the rich lymphatic anastomosis mentioned above. It may therefore require removal of the gallbladder to break up the vicious circle. Infection of the gallbladder may be acute or chronic.

Acute Cholecystitis. Acute inflammation of the gallbladder is not as common as chronic cholecystitis, but it is of importance surgically because of the acute abdominal symptoms produced. It is usually associated with cholelithiasis. Indeed, in most cases a stone impacted in the neck of the gallbladder, with the consequent production of obstruction of the cystic duct, is frequently an important factor in pathogenesis (Fig. 17). When the organ is the seat of an acute infection the wall becomes thickened and edematous, with a reddened serosal surface upon which fibrin may be deposited. Lymphocytes and leukocytes are found throughout, the number of the latter being dependent upon the acuteness of the process. The external reaction is probably a precursor of the formation of numerous adhesions to other organs (Fig. 18). The cystic duct may also be obstructed by edema and adhesions created by inflammation. When this occurs in the presence of an acute infection, the contents of the gallbladder are apt to become purulent, thereby producing a condition known as *empyema of the gallbladder*. Andrews has shown that, on many occasions, this purulent-like material consists chiefly of mucous and cholesterol crystals and that in such cases the culture is negative, thereby suggesting that on these occasions infection plays a minor role in pathogenesis. The secretion of mucus, the pouring out of exudate, and the production of pus increase the distention and the size of the gallbladder. Within a few days after the production of the obstruction, the green-

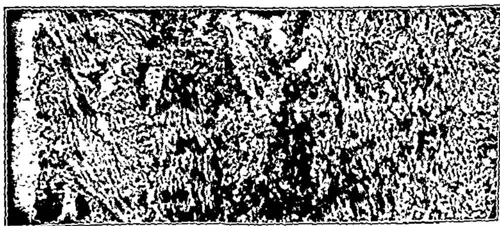


Fig. 18. Photomicrograph of subacute cholecystitis. Note that the mucosa has been eroded away and the submucosa is covered with exudate. The muscularis (M) is comparatively normal. Most of the thickness of the wall consists of fibrous tissue (F), only a part of which is shown.



Fig. 19. Photomicrographs showing chronic cholecystitis. A, diffuse mild lymphocytic infiltration and only slight thickening of the wall; the musoca is intact. B, the wall of this gallbladder is greatly thickened because of numerous attacks of subacute inflammation. Lymphocytic infiltration is more extensive than in A.

ous organs (Fig. 20). If the cystic duct becomes obstructed because of adhesions or a stone, but in the absence of acute inflammation, a condition known as *hydrops* may develop; after several days, the brownish green color of the gallbladder contents fades because of destruction or absorption of bile pigment. The gallbladder becomes distended because of the secretion of mucus by the mucosa and may attain an enormous size, often becoming palpable as a smooth, only mildly tender mass in the upper abdomen. The contents of the gallbladder in such an instance is sterile and is known as *white bile,* since the most important constituent is mucus excreted by the gallbladder and because bile pigments are absent. If the contents become infected, an *empyema,* as discussed previously, will result; in such instances, operative therapy becomes more urgent.

The function of the chronically inflamed gallbladder, as determined by cholecystography, may or may not be seriously impaired. It is quite probable that during the acute attack, the gallbladder function is lost but, when healing takes place, is to a great extent regained. Microscopically, the wall is thickened by fibrous tissue and infiltrated by lymphocytes. Granulation tissue and plasma cells are abundant. The muscle and elastic tissue may be destroyed and replaced by fibrous tissue and fat cells. On rare occasions, the wall of the gallbladder becomes calcified to such an extent that it may be demonstrable by x-ray.

Frequently, the gallbladder mucosa is the seat of polypoid enlargement of the villi. These villi contain yellowish deposits of cholesterol or cholesterol esters which are visible to the naked eye (Fig. 21). The term *strawberry gallbladder* has been applied by MacCarty to this condition (1910), although it was probably first recognized by Moynihan (1909). There is no evidence that this disease has any clinical significance except that stones are frequently associated.

genital organs. Tenderness associated with renal colic is more apt to be acute posteriorly; examination of the urine rarely fails to reveal erythrocytes or pus cells; fever and leukocytosis are usually absent in nephrolithiasis. Occasionally, the pain encountered in gastric crises associated with tabes dorsalis may be similar to that produced by acute cholecystitis. Muscle spasm and abdominal tenderness, however, are usually much less prominent. Moreover, fever and leukocytosis are absent in the gastric crises. Neurologic examination should reveal signs of tabes. Pain of cardiac origin occasionally simulates that of cholecystitis, but rarely indeed will a careful consideration of the manifestations fail to establish differentiation between these two diseases.

TREATMENT. Although the majority of surgeons (27, 28, 29) favor prompt operation for most patients with acute cholecystitis, there are many very competent surgeons who favor conservative treatment (30, 31) unless an acute complication, such as perforation or impending perforation, develops. The high frequency of diagnostic error is one of the important contraindications for prompt operation; however, it is true that immediate operation eliminates much discomfort during resolution of the acute attack and shortens the period of disability. An important disadvantage of delay lies in the fact that, if operation is performed 10 to 14 days after the attack subsides, the gallbladder is still much more seriously inflammed than it is during the first day or two of the acute attack; removal of the organ is therefore more difficult than when performed shortly after onset of symptoms. The authors agree with Boyden (32) that, if the patient is seen within 48 hours after onset of symptoms and the diagnosis appears quite accurate, prompt operation is advised. In our opinion, if the patient is not seen within this period since onset of symptoms, the conservative procedure will usually be indicated. However, if the symptoms do not subside under 24 to 48 hours with conservative therapy, and particularly if there is an increase in such manifestations as pain, muscle spasm, and fever, along with a rising leukocyte count, immediate operation will be indicated on the assumption that a serious complication, such as gangrene or perforation, may be present, thereby demanding surgical relief. Obviously, if signs of peritonitis are present upon admission, emergency operation will be indicated on the assumption that gangrene or perforation has already taken place. At operation, cholecystostomy or cholecystectomy may be performed, depending upon the age of the patient and the condition of the gallbladder. At operation, the surgeon should investigate the common duct because stones will be present in the common duct in 5 to 10 per cent of cases (32).

If the gallbladder is so badly diseased and densely adherent that removal will jeopardize the patient's life, it may be advisable to perform cholecystostomy. However, relief from cholecystostomy is not permanent in that symptoms of more than trivial character will develop within five years following cholecystostomy in 25 to 35 per cent of cases. In seriously ill patients, the risk of operation is greatly reduced by adequate preoperative treatment, including intravenous fluids, transfusion, and combined chemotherapy. This is particularly true in elderly individuals. A study of results in numerous reports will not reveal a significant difference in the mortality rate of patients treated by prompt operation compared to those treated conservatively (33). The mortality rate in acute cholecystitis is much higher (5 to 10 times) in patients over 60 or 65 years of age than in patients under this age (29).

Chronic Cholecystitis. This is an extremely frequent condition, but on many occasions it offers marked difficulty in diagnosis. There is sufficient difference in the manifestations, treatment, and prognosis of patients with cholecystitis due to the presence or absence of stones that the two conditions are considered separately. Cholelithiasis is discussed later in this chapter.

PATHOLOGY. Chronic cholecystitis may develop as a sequel to acute cholecystitis, but more frequently develops insidiously. The gallbladder wall, because of bacterial invasion or a chemical inflammation, becomes thickened, largely because of the deposition of scar tissue (Fig. 19). Adhesions in varying degree are found externally (pericholecystitis) and may involve the contigu-

group of symptoms alone is, therefore, only suggestive evidence of the presence of gallbladder disease. Pain is of much more value in establishing the diagnosis. The pain usually varies in extent, occurring in mild intermittent attacks which in reality may be due to transient acute inflammation and is localized in the right upper quandrant, but frequently radiates toward the tip of the scapula. In a detailed study of over 200 cases made by Harridge and Helsby (34) the attack lasted less than one hour in 42 per cent of cases. Furthermore, in 43 per cent of their cases, the pain, while it lasted, was continuous; it was intermittent or colicky in the remainder. *After an extensive study of patients* at the Mayo Clinic, Smith (34a) noted that 24 per cent of patients with cholecystic disease had pain left of the midline, although many of them had pain also on the right.

Nausea is encountered frequently, but vomiting is uncommon except during severe attacks. Rarely is there any relation of the pain and discomfort to meals, except that fatty food is poorly tolerated. Constipation is a frequent complaint. Fever and leukocytosis are rarely present. Jaundice, if present, is usually associated with a stone in the common duct except that mild jaundice is occasionally produced by an associated hepatitis. Occasionally, patients with chronic cholecystitis have dyspepsia of more or less constant severity without attacks of severe pain. Such a clinical picture, however, offers great diagnostic difficulty since it is produced by so many other diseases.

Examination of the abdomen reveals tenderness over the right upper quadrant, the intensity of which varies with the severity of the disease. Frequently the infection subsides to such an extent that the patient will be free from symptoms or signs for months at a time only to have them recur. Tenderness under the right costal margin (over the liver edge) may be present and is a manifestation of the associated hepatitis (Graham).

Evidence has been presented (Alvarez, 1934) to suggest that allergy may affect the gallbladder. Whether or not it is a true allergy cannot be determined, but it is definitely known that certain foods, such as chocolate or bananas, may initiate attacks of severe right upper quadrant pain.

Differential Diagnosis. It may be extremely difficult to differentiate chronic cholecystitis from peptic ulcer, but symptoms of the former disease are rarely related to meals, whereas in peptic ulcer there is usually a history that discomfort occurs two or three hours after meals and is relieved by eating or ingestion of alkali. The most reliable method of distinguishing peptic ulcer from cholecystitis is by x-ray, especially cholecystography and the barium meal. The two diseases frequently occur together. Recurring attacks of mild acute appendicitis may simu*late chronic cholecystitis if the appendix is* adherent high in the abdominal cavity. However, appendicitis is rarely associated with dyspepsia; pain and tenderness are the chief manifestations. Spastic colitis associated with constipation is perhaps the most difficult disease to differentiate from chronic cholecystitis. Usually the tenderness in spastic colitis is diffuse, limited somewhat to the colon, and not localized to the right upper quadrant. Osteoarthritis of the spine is commonly confused with cholecystitis, and even when the latter condition is present the most annoying symptoms may be due to the spinal lesion. At times, small diaphragmatic hernias (particularly those of the hiatus type, see p. 856) will produce a variety of digestive symptoms including epigastric distress, bloating, and belching so commonly observed in cholecystitis. Intestinal allergy may likewise simulate the manifestations of chronic cholecystitis, but the pain and tenderness are more apt to be diffuse. On rare occasions, tuberculosis of the spine may produce pain, tenderness, and so forth, in the upper quadrant. This condition occurs just often enough to demand inspection of the spine in patients suspected of having chronic cholecystitis. In all these conditions, cholecystography should lead to the correct diagnosis. It should be emphasized, however, that the demonstration of a pathologic gallbladder by cholecystography *does not necessarily mean that the symptoms are of cholecystic origin,* inasmuch as it is known that a pathologic gallbladder may remain silent for years. Moreover, chronic cholecystitis is so common that it will frequently *be present along with some*

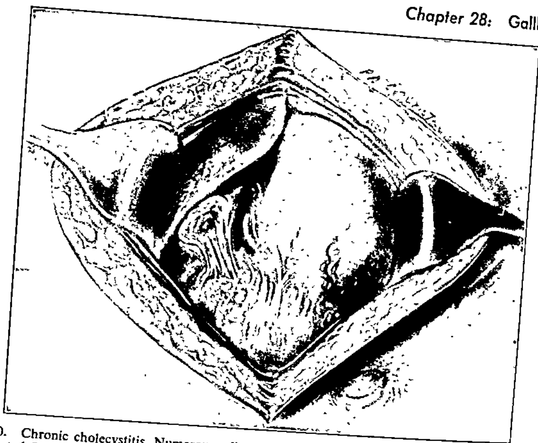


Fig. 20. Chronic cholecystitis. Numerous adhesions to contiguous organs, particularly the omentum, may be noted. There is also a localized area of hepatitis on the superior surface of the liver, adjacent to the gallbladder.

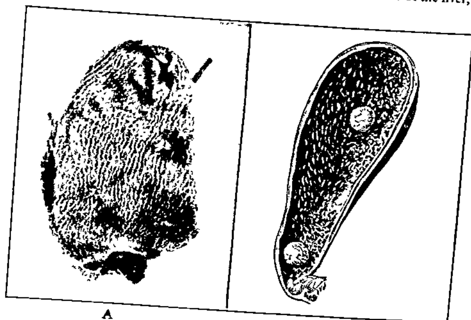


Fig. 21. Cholesterosis of the gallbladder. A, without stones. B, with stones.

Clinical Manifestations. The presence or absence of stones influences the clinical picture as discussed later. One of the most common symptoms complained of in chronic cholecystitis is *dyspepsia*, which may include such symptoms as epigastric distress, bloating, pyrosis (heart burn), flatulence, anorexia, belching, and mild pain. It must be emphasized, however, that innumerable diseases may produce dyspepsia; the presence of this



Fig. 22. Photomicrograph of gallbladder with cholesterosis to illustrate one of the possible mechanisms in the formation of gallstones. The section was made from unfixed frozen tissue and is unstained, but is viewed under polarized light for determination of the presence of cholesterol; the white material in the enlarged villus is cholesterol. It seems logical to assume that the large cholesterol-containing villus might be detached by rupture of the stalk, and become the nucleus of a gallstone.

a criteria of obstruction, Cattell and associates classify all sphincters as obstructed if a 3 mm. probe cannot be passed through it readily. Treatment consists of section of the fibrosed sphincter.

Cholelithiasis. Gallstones nearly always contain cholesterol; many also contain calcium and bile pigments. They may be solitary or multiple. They vary in shape from the round single stone to the faceted multiple stones. Many years ago it was thought that obstruction, stasis, and infection were the important factors in the formation of gallstones. However, Andrews and associates (40) have shown that a reduction in the ratio of cholesterol to fatty acids or bile acids by absorption of bile salts through the gallbladder wall is very important in the etiology of gallstones, particularly the cholesterol type (Fig. 22). Robertson (41) has corroborated this view, adding that hormonal influence may be important; he postulates further that secretion of an abnormal mucoid substance by the gallbladder mucosa might actually act as a binding agent and organic framework for the precipitated elements of the bile. Phemister and associates (1939) have called attention to the role of infection in the formation of calcium carbonate stones.

At least 50 per cent of the gallbladders removed surgically throughout the country contain stones (Fig. 23). In a study of 16,936 autopsies, Robertson and Dochat (42) found gallstones in 31.7 per cent of women past the



Fig. 23. *Cholelithiasis.* The stones in this instance completely filled the gallbladder.

other disease which may be producing the symptoms, and be of much more importance than the gallbladder disease. Duodenal drainage, with study of the centrifuged sediment, is of diagnostic value. The finding of cholesterol crystals, calcium bilirubin, bile pigment particles, and pus cells indicates the presence of stones.

TREATMENT. There is little to offer the patient with chronic cholecystitis other than surgical procedures (cholecystectomy and, rarely, cholecystostomy), except that occasionally changes in the diet, such as elimination of fatty food, will be helpful. It should be emphasized, however, that operation should not be recommended unless the diagnosis is definite and symptoms, especially pain, are sufficient for the patient to demand relief. We wish to emphasize that cholecystectomy will not cure more than 60 per cent of patients when dyspepsia is present without pain, particularly when stones are absent.

Cholecystectomy is much to be preferred over cholecystostomy because of the great tendency for the latter to be followed by recurrence of symptoms at a later date. The *operation* for removal of the gallbladder is associated with certain technical pitfalls which, if not avoided, will lead to deleterious sequelae. During the procedure of cholecystectomy, extreme care must be exercised in the identification of the cystic and common duct lest the latter structure be injured. Such a tragedy is avoided by careful dissection at the neck of the gallbladder, which will facilitate identification of the ducts and thereby minimize the possibility of inflicting injury upon them. The carefully isolated cystic duct is clamped, cut, and the stump ligated. Identification of the cystic artery will also enable its ligation, so that removal of the gallbladder from below upward may then be performed with little or no bleeding. It is advisable to insert a rubber dam drain down to the stump of the cystic duct; if drainage is slight, it is removed in 48 hours. Cholecystectomy is apt to produce more postoperative discomfort (gas pains and the like) than most other types of abdominal operations. For this reason, adequate amounts of morphine or similar hypnotic should be given during the first two or three days. Gastric decompression with a tube for a day or two after operation will minimize the postoperative distress. The use of vitamin K for obstructive jaundice is discussed on page 676. Results of cholecystectomy for gallbladder diseases are very good (80 to 90 per cent) if the diagnosis is correct. Aged people tolerate simple surgical procedures on the biliary tract very well, but in complicated operations the mortality rate will be 5 to 10 times higher in aged patients than in young patients (35, 36). It is for this reason that indications for cholecystectomy may be stronger in aged patients to remove the gallbladder before complications develop.

Poor results following cholecystectomy may be attributed to such factors as error in diagnosis, overlooked stones in the common duct, pancreatitis, technical errors at operation, and fibrosis of the sphincter of Oddi.

Fibrosis of the Sphincter of Oddi. This lesion has been recognized only recently, but for the past 10 or 20 years the term *biliary dyskinesia* has been applied to a partial obstruction at the terminal end of the common duct due to spasm of the sphincter. It is now agreed by most surgeons that fibrosis is the important factor in the obstruction, although spasm may have been a prominent feature in its incipiency. Pain is a prominent manifestation; the pain is similar to that of gallbladder disease, but del Valle (who first performed sphincterotomy for this lesion in 1925) describes the pain of obstruction from fibrosis of the sphincter as radiating toward the first lumbar vertebra and left scapular angle whereas the pain of gallbladder colic radiates to the mid-thorax, right hemithorax, and right scapular area. However, in our experience (37) there has not been a significant difference in the pain encountered in the two conditions. Wise and O'Brien (38) find intravenous cholangiography helpful in making the diagnosis. They postulate that ducts (on x-rays with 30 per cent magnification) measuring 8 to 15 mm. are probably partially obstructed, and ducts measuring over 15 mm. are invariably obstructed; they believe also that density of the shadow is of diagnostic value. Cattell and associates (39) have studied 100 consecutive patients with this condition and noted that 81 had had a previous cholecystectomy. Stones were present in 38 per cent of their series; 30 of them were jaundiced or had a history of jaundice. As

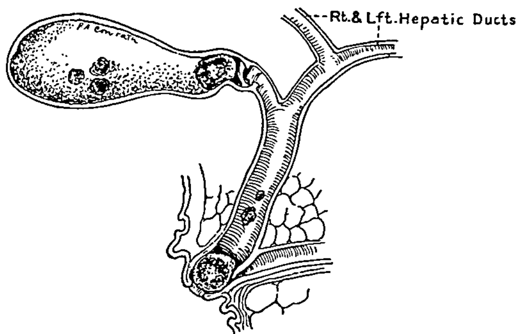


Fig. 24. Drawing to illustrate the common locations of gallstones in the biliary system. Impaction in the cystic and common duct as depicted in the illustration is quite common.

age of 40 years, and in 16.2 per cent of men past the age of 40. Multiple pregnancies have been considered predisposing factors in the development of gallstones; however, in their intensive statistical study, Robertson and Dochat (42) found no greater incidence in women with children than in women who had borne no children. Cholecystitis caused by the typhoid baccillus may be encountered with or without stones.

The *clinical manifestations* produced by biliary calculi vary tremendously. On many occasions the patient may carry gallstones in his gallbladder the greater part of his life without experiencing any symptoms whatever. On the other hand, symptoms may develop as soon as the stones are formed and provoke a wide variety of clinical manifestations.

The clinical picture produced by gallstones *depends on their location* (Fig. 24). When in the *gallbladder*, stones frequently are silent or cause only mild symptoms of dyspepsia. As a rule, however, the pain associated with stones in the gallbladder is more severe and more apt to occur in attacks than it is in chronic cholecystitis without stones. When a stone becomes lodged in the *cystic duct* the pain is usually severe; the clinical picture produced by this condition is frequently spoken of as biliary colic, although a better term is acute cholecystic obstruction. The origin of the pain is uncertain but may be associated with such factors as spasm or contraction of the gallbladder, by distention of the duct, or by the inflammation associated with the stone. The pain is apt to occur in paroxysms with tenderness and pain remaining in the intermissions. These attacks are apt to be of short duration but may last for several days; unlike stone in the common duct they are not associated with jaundice, except when a coexisting hepatitis is present. If the obstruction to the cystic duct does not subside, acute cholecystitis may develop, or the gallbladder distend and its contents become colorless (white bile) because of the disappearance of the bile pigment (hydrops of the gallbladder). If the contents of a hydrops become infected, empyema of the gallbladder results.

When the stones are located in the *common duct* a different clinical picture manifests itself, although stones may occasionally be present and produce very few manifestations. Usually, however, the common duct at the sphincter of Oddi becomes occluded by the stone; more severe manifestations then develop. An intermittent colicky pain in the epigastrium or right upper quadrant is usually present. At the onset of obstruction, nausea

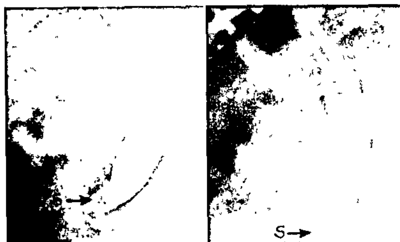


Fig. 27. Postoperative cholangiograms revealing stones. In this patient the surgeon overlooked a stone, an accident which may infrequently happen to any good surgeon. The shadow is relatively the same in the two films, taken on the same day.

fistula is produced (see below). In these patients, it is frequently necessary to institute special preoperative preparations, such as bed rest, high carbohydrate and fluid intake, and the like (see Ch. 9). Extreme precaution must be taken against hemorrhage during and after operative procedures in the presence of jaundice since such patients occasionally have a delayed coagulation time of the blood. Administration of vitamin K with bile salts, intravenous glucose, and transfusions are effective in treatment. (See also p. 676.)

When the stones are producing symptoms, such as pain and troublesome dyspepsia, indications for cholecystectomy are clear cut. However, when few or no symptoms are present, there is disagreement as to whether or not operation is necessary, except that all would agree to removal of a stone from the common duct even though it were producing no symptoms. When stones in the gallbladder are asymptomatic, the authors consider age and life expectancy important in the decision regarding operation. If the stones are asymptomatic and found accidentally in a patient 65 or more years of age, operation would appear not to be indicated. On the other hand, if symptoms are present in the aged, indications for operation (probably cholecystectomy) are actually stronger than in younger patients because old people tolerate complications of gallbladder disease so poorly and complications represent the serious aspects of gallbladder disease. If asymptomatic stones are found by x-ray in a person 30 to 40 years of age, and life expectancy is normal, cholecystectomy would definitely appear indicated since the danger of ultimate development of one or more complications, such as stones in the common duct, hepatitis, pancreatitis, carcinoma, hydrops, and empyema, over a period of many years would appear great enough to justify operation.

Occasionally, gallstones exert a reflex effect deleterious to angina pectoris and make the symptoms and effects of that disease worse. It has been shown by numerous workers (46, 47, 48) that cholecystectomy in such cases will be very beneficial. However, great care must be taken in choosing these patients for operation, particularly regarding time, since an operation within three months following a myocardial infarct is dangerous and, in fact, frequently fatal.

Biliary Fistula. As mentioned above, a biliary fistula is purposely produced after the common duct is opened for exploration and the removal of stones. Ordinarily, such a fistula is of short duration, the T-tube being removed in two or three weeks. Drainage of bile through the resulting sinus tract may continue for a few days, after which time it closes spontaneously; closure is accompanied by a gradually increasing amount of pigment in the stool which changes from an acholic to a pigmented character.

Persistent drainage of bile for more than

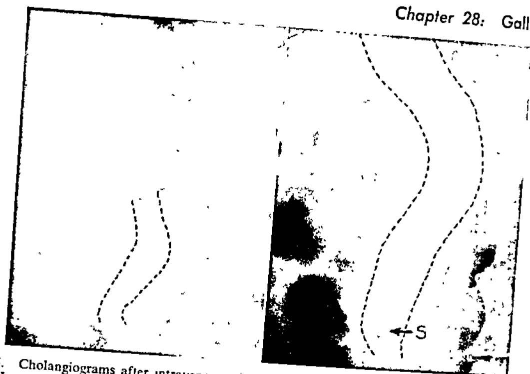


Fig. 25. Cholangiograms after intravenous administration of cholografin. The shadow on the left is normal. However, on the right, the common duct is moderately dilated, and a negative shadow of a soft stone "S" (cholesterol) is observed in the terminal end.

Fig. 26. Postoperative cholangiograms (normal). When choledochostomy is performed, a postoperative cholangiogram utilizing 30 per cent diodrast (or a similar media), is taken before the T-tube is removed (about 12 days postoperatively). Left, no stones were found in the duct, the diameter of which is normal. Right, stones were found and removed; the duct is slightly enlarged. Note that the pancreatic duct is filled. This is not necessarily abnormal; it may be due to temporary spasm or fibrosis of the sphincter of Oddi.

a *preliminary open film of the gallbladder* region, because putty-like material or calcium deposited in the wall may cast a shadow which resembles a normal gallbladder but is not due to administration of dye. One of the most serious pitfalls in cholecystography occurs because asymptomatic cholecystitis is *frequent and because clinicians, on finding* cholecystographic evidence of a diseased gallbladder, may cease searching for other diseases (such as carcinoma of the colon), and thus overlook the lesion which may in reality be producing symptoms.

Nonvisualization of the gallbladder after *cholecystography may mean that the concentrating* power of the gallbladder has been lost or that an obstruction at the cystic duct is present. If a shadow of the gallbladder is obtained, stones will show up as "negative" or "positive" defects in the films, i.e., cholesterol stones displace dye and produce negative shadows, whereas hard calcium stones show up as areas of increased density, which are spoken of as "positive" shadows (Figs. 28, 29). A distortion of the gallbladder shadow which is consistent in more than one film is indicative of adhesions (pericholecystitis). It should be emphasized, however, that the *dye must be excreted by the liver before it* can enter the gallbladder; the presence of jaundice interferes markedly with the production of a gallbladder shadow because of numerous factors, such as inability of the liver to excrete the dye, and edema of the gallbladder wall.

For years tetraiodophenolphthalein and its isomer, phenoltetraiodophthalein, were the substances used in the performance of this test. In 1940, Dohrn and Diedrich (51) introduced another contrast media, β-(4-hydroxy-3,5-diiodophenyl)-α-phenylpropionic acid, known as iodoalphionic acid or *priodax; it is very satisfactory and is given in* a dose of 3 grams orally the night before x-ray pictures are taken. If there is doubt about the accuracy of a test a double dose of priodax may be used. Numerous other compounds have been found suitable for cholecystography. Of those recently introduced 2-(4-hydroxy-3,5-diiodobenzyl)-cyclohexane carboxylic acid (monophen) and 3-(3-amino-2,4,6-triiodophenyl)-2-ethylpropanoic acid (telepaque) should be mentioned. The latter is considered by many radiologists and surgeons to be more satisfactory than the others mentioned above. It is also given the night

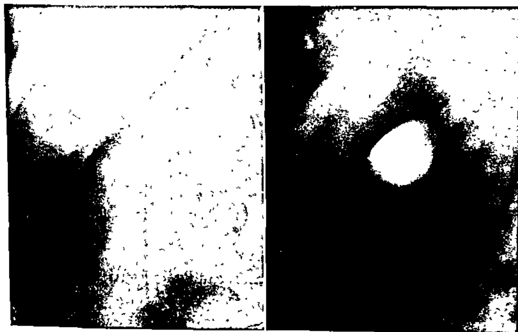


Fig. 28. *Stones revealed by oral cholecystography. In each patient the density of the gallbladder shadow* (after oral ingestion of telepaque) is normal. On the left a negative shadow (cholesterol stone) is observed, whereas on the right a positive shadow (stone containing some calcium) is observed.

several weeks is usually indicative of an obstruction in the common duct distal to the opening made at operation. Injection of radiopaque substances, such as diodrast or sodium diatrizoate (hypaque), into the tract will allow visualization of the larger bile ducts by x-ray. The obstruction can readily be demonstrated by this procedure (cholangiogram); if produced by a stone left in the common duct, the stone can usually be visualized. Regardless of the cause of the persistent obstruction, a secondary operation will usually be indicated, although it has recently been learned (49) that about two thirds of these "stone" shadows will disappear in two to six months. It cannot be proved that these shadows were stones and not air bubbles. The T-tube was clamped to allow bile to flow over the stones. Two to three grams of bile salts were given orally per day to these patients, but it is not clear whether or not this drug was of value. Conservative treatment of this type should not be tried if the patient is jaundiced or there is evidence that the common duct is completely obstructed.

Persistent loss of bile is poorly tolerated by all patients, particularly in males of advanced age. An important symptom is a severe degree of anorexia which may be so marked that it creates a positive loathing for food. Dehydration and hypochloremia are common, especially when the loss of bile is considerable and there is associated vomiting and/or diarrhea. Malnutrition is frequent, developing either insidiously or with rapid loss of weight. There is often a tendency toward spontaneous bleeding due to vitamin K deficiency; the mechanism is the same as in jaundice (see p. 675). *Treatment* is difficult, but the symptoms rapidly improve as soon as bile flow into the intestine becomes reestablished. Bile salts by mouth may be effective, but they induce a further loss of bile since they exert a cholagogue action. Feeding the patient a portion of his own bile is usually very helpful in eliminating anorexia, loss of weight, and other asthenic symptoms, but not all patients will be able to drink it unless it is well disguised. Insertion of a small stomach tube will eliminate this disadvantage but is likewise disagreeable. If the fistula does not close in a few weeks, operation will be indicated to relieve the obstruction. Preoperative preparation, including administration of vitamin K and so forth, as previously described, will be necessary.

A spontaneous biliary fistula is rare but may occur if the gallbladder becomes adherent to the abdominal wall and ruptures to the outside. Rare, also, is rupture of the gallbladder or a large bile duct (usually by abscess formation) through the diaphragm into the lung and bronchus, thereby producing a bronchobiliary fistula, which is characterized by the expectoration of bile-stained sputum. More commonly a stone perforates the wall of the gallbladder into the colon or small intestine, with formation of a fistula which, in time, will usually close. Such stones may actually be large enough to lodge in the small intestine and produce an acute obstruction.

Cholecystography. Cholecystography refers to the visualization of the gallbladder in an x-ray film following the administration to the patient of a radiopaque substance which is carried in the bile to the lumen of the gallbladder and is concentrated there in sufficient amount to cast a shadow on the x-ray film. This diagnostic procedure was discovered in 1924 by Graham and Cole (50). A substance capable of fulfilling such requirements must have two prerequisites, namely, be excreted primarily by the liver and contain elements of sufficient atomic weight (e.g., iodine) to be impervious to the x-ray. In individuals with a normal gallbladder, a shadow of the organ is obtained within a few hours after oral or intravenous administration of the contrast medium. Before the advent of cholecystography, there was no direct clinical method of gaining objective information as to the presence of abnormal changes in the gallbladder, except the demonstration of calcified stones by the plain x-ray plate; the drainage of gallbladder bile through a duodenal catheter (Lyon's test) yields but indirect evidence of disease and often gives equivocal findings.

Production of a dense shadow of the gallbladder (which usually reveals a change in size on successive films) is indicative of a normal gallbladder. Absence of shadow and evidence of stones within the gallbladder shadow (as produced by the dye) are extremely reliable indications of a pathologic gallbladder. It is desirable, however, to obtain

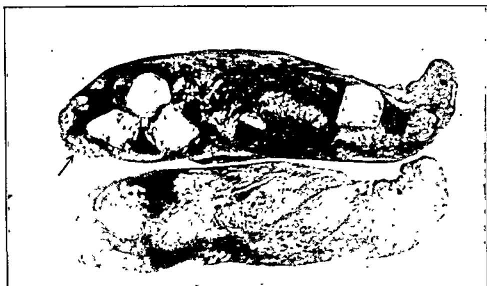


Fig. 30. Carcinoma of the gallbladder. The organ contained stones, and, as is likewise common in carcinoma of the gallbladder, considerable inspissated bile and mucus. The patient had symptoms typical of chronic cholecystitis. Although longitudinal section of the gallbladder revealed an unusual thickening at the fundus, as indicated by the arrow, the presence of the carcinoma was not evident until the microscopic section was obtained. In spite of the performance of a cholecystectomy in this early stage, the patient returned 18 months later with a metastasis in the liver, thereby illustrating the extremely invasive character of carcinoma of the gallbladder.

most common etiologic factor is accidental injury during operative procedures upon the biliary tract. In a recent study of 122 cases by one of the authors and associates (52), 72 per cent could definitely be attributed to operative trauma. An additional 18 per cent were of inflammatory origin, but at least half these were quite certainly related to operative errors. The stasis of bile created by the obstruction encourages infection, and symptoms are apt to occur in attacks consisting of chills, fever, jaundice, pain, malaise, and so forth. The only hope for relief lies in surgical therapy. Such procedures as resection of the stricture with anastomosis of the two ends of the duct over the arm of a T-tube brought out through an opening in the common duct above or below the suture line, implantation of the proximal end of the duct into the stomach or duodenum, implantation of the duct into a loop of jejunum, and implantation of the duct into a Roux Y-arm of jejunum (52) are methods utilized in repair. Perhaps the majority of surgeons favor the latter method although an end-to-end anastomosis is preferred when it is possible.

On rare occasions, such tumors as *carcinoma,* adenoma, and polyp, may be primary in the ducts. Carcinoma may develop at any point in the common hepatic duct or the common duct. More commonly it is located in the *ampulla of Vater.* The symptoms produced by such tumors are similar to those observed in carcinoma of the pancreas (as described later). Important in the differentiation from carcinoma of the pancreas are the facts that, in carcinoma of the ampulla of Vater, the jaundice is apt to be intermittent and that blood is usually found in the stool. Diagnosis is often made with certainty only at the time of operation, especially if the surgeon opens the duodenum for direct inspection of the ampulla of Vater. Since the development of a technic of resection by Whipple and associates (1935), the majority of these tumors are amenable to surgical treatment because they grow slowly. Prognosis is therefore so good that the patient should not be deprived of the benefits of resection if the tumor is operable. *Cysts* of the common duct ai extremely rare and usually are congenital in origin.

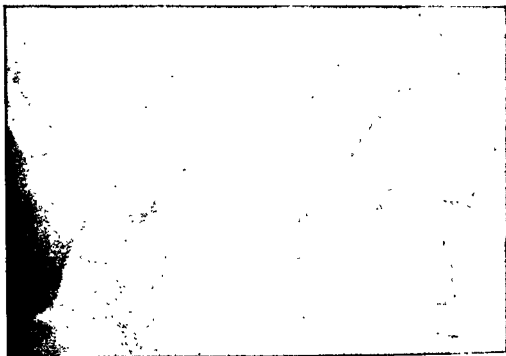


Fig. 29. Multiple stones in gallbladder. Oral administration of telepaque revealed a normally functioning gallbladder, but numerous negative shadows of cholesterol stones are observed.

before (10 hours before x-rays) in a dose of 3 grams; a double dose may be given.

In oral cholecystography x-ray pictures are taken on two or three occasions following the administration of the dye (10 to 12 hours after ingestion of the tablets) so that the presence of stone shadows may be confirmed. An absence of a shadow is 100 per cent evidence of gallbladder disease unless serious hepatic insufficiency exists or the agent was vomited or not taken.

Tumors of the Gallbladder. *Primary carcinoma* of the gallbladder is the most common of these tumors and constitutes about 3 or 4 per cent of all cases of carcinoma. Carcinoma of the gallbladder rarely occurs without the presence of stones in the organ. The relative frequency of carcinoma compared to cholelithiasis varies in different clinics, but on the average 4 to 5 per cent of all patients proved to have stones in the gallbladder by operation or autopsy have associated carcinoma of that organ. Unfortunately, carcinoma of the gallbladder may develop insidiously. The symptoms may occur late and be insignificant; they resemble those discussed under chronic cholecystitis. In the early stages of the disease, pain is usually slight but may be very troublesome later on. The diagnosis is rarely made before operation. If the disease is found to be local at the time of operation, the gallbladder obviously should be removed (Fig. 30). The tumor is so invasive that, even though it is early and small, cholecystectomy is rarely curative.

Small *benign papillomas*, which consist in reality of hyperplasia of the villi, are rather common. Papillomatous structures due to deposition of cholesterol have already been mentioned. Other tumors, such as adenoma and sarcoma, do occur but only on rare occasions. True adenomas have very little clinical importance.

THE BILE DUCTS

Stones in the common duct and infection of the intrahepatic bile ducts (cholangitis) are common and have already been discussed. Infection may also affect the extrahepatic bile ducts, especially when a stone is impacted in the common duct. On such occasions, white bile and even pus may be found in the choledochus at operation. *Strictures* are not uncommon and may occur either in the ductus choledochus or the common hepatic duct, usually in the former. They may be infectious or traumatic in origin. Unquestionably, the

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Fig. 1. Demonstration of a common passageway by cholangiogram performed during operation. On the left side a needle has been inserted into the cystic duct (spiraled by the valves of Heister) and opaque material fills the bile duct in liver and down to the junction of common bile duct with pancreatic duct. A metallic bucket on the end of a nasogastric tube is placed to deliver 0.1 hydrochloric acid to the sphincter of Oddi and create spasm of the muscle. Resistance to flow at this point forces the fluid into the pancreatic duct, which is outlined to the tail of the pancreas (arrow).

COMMON BILE DUCT. 1. Many years ago Opie (1) described an instance of acute pancreatitis in which bile had been diverted into the pancreatic duct by a small stone lodged in the ampulla of Vater. The common bile duct and pancreatic duct opened into this ampulla, thus creating a common channel. Archibald (2) some years later proposed that a resistant sphincter of Oddi, which controls the outlet of this ampulla into the duodenum, might divert bile or pancreatic juice from its proper duct system into the other. The actual incidence of a functional common channel is difficult to determine in the cadaver because the sphincter of Oddi during life can extend over both openings and create a common space, whereas the cadaveric position of the sphincter is retracted. In studies with radiopaque materials in the ducts of a large series of patients operated upon for biliary and pancreatic inflammatory disease or by direct observation at operation, a common channel is present in practically all (3) (Fig. 1).

2. Normally both bile and pancreatic juice are delivered to the duodenum as a result of the presence of food. The mechanism of secretion is through the elaboration of the gastrointestinal hormone, secretin, by duodenal mucosa. Secretin is carried by the blood to the pancreas where it acts directly on pancreatic cells. At the same time, the sphincter of Oddi relaxes and juice flows into the duodenum. Resistance to flow by a sphincter which does not relax adequately raises intraductal pressure and brings about distention of the ducts. It can be shown that most of the pain associated with disorders of ductal systems is caused by distention.

3. Experimentally, inflammation of the pancreas can be produced by the injection of bile into the pancreatic duct.

29

THE PANCREAS

JOHN H. MULHOLLAND

Embryology. A bud of ectoderm pouts out of the primitive duodenum and gives rise to all of the ducts, glands, and appendages of the biliary-pancreatic system. This common origin is the background for complex interdependence and interactions between the two main digestive glands (liver and pancreas) and the upper gastrointestinal tract (duodenum, pylorus, and stomach) in maturity. The pancreas originates as ventral and dorsal lobes which rotate and fuse into the adult single structure. Abnormalities in these processes may give rise to persistent variations which create surgical problems (e.g., annular pancreas).

Anatomy. In the adult, the pancreas is a retroperitoneal organ closely bound to the lesser curve of the duodenum at its head and extending its neck, body, and tail obliquely across the abdomen to the hilum of the spleen. It is a soft, yielding organ which conforms to the rigid curving posterior vertebral bodies and rib cage until the tail extends into the lienorenal ligament. Because of its deep situation and soft consistency, it is not palpable through the abdominal wall in its normal state, and surgical exposure of its entire length is an exacting maneuver. Direct proximity of the neck and body to the rigid vertebral bodies exposes these parts to injury when blunt trauma to the abdomen occurs. Rupture of the pancreas as a result of such forces is a serious event and difficut to diagnose. Depending upon the extent of damage to the pancreas, the outcome may be a rapidly disastrous inflammation or extravasation of pancreatic juice along anatomic pathways defined by peritoneal layers. The latter will be discussed under a consideration of pancreatic pseudocysts below.

Other anatomic features of the pancreas which are of surgical import are the so-called islet cells which produce internal secretions concerned with carbohydrate metabolism (insulin, glucagon) and more obscurely, with gastric acid production. Surgical disorders of these secretions are discussed in Chapter 39.

The acinar and ductal system produces an external secretion which is concerned with intestinal digestion. Acinar cells are large and conical shaped. They are so arranged that the apex of the cone is directed toward the central collecting area of the acinus, which in turn joins to other fine ducts of a lobule. Secondary lobules are groups of acini with loose connective tissue envelopments which carry vessels and nerves. Central collecting ducts join other larger cell-lined tubes at right angles. As the ducts become larger, the lining duct cells change from flat cuboidal to low columnar and finally to columnar epithelium. These duct epithelial cells secrete a mucoid material, and possibly the fluid and bicarbonate portion of pancreatic juice; acinar cells secrete the digestive enzymes.

There are several anatomic and physiologic features of the pancreas which are important in the production of the disease.

RELATIONSHIP OF THE MAIN PANCREATIC DUCT TO THE SPHINCTER OF ODDI AND THE



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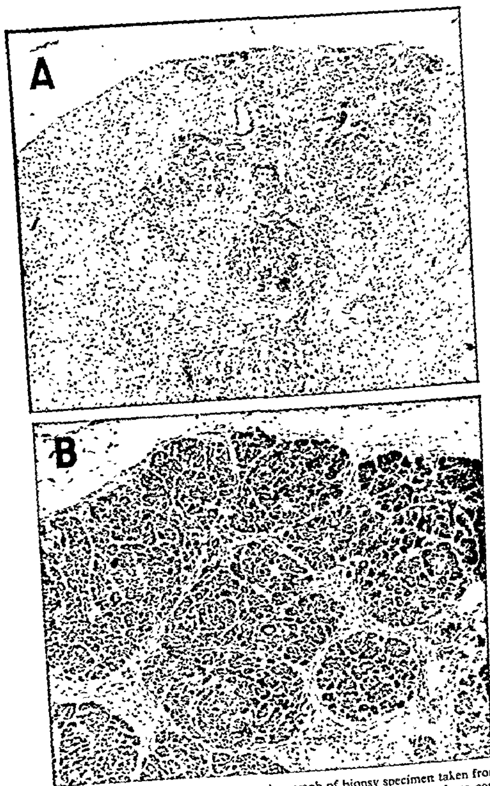


Fig. 2. Regeneration of the pancreas. A, photomicrograph of biopsy specimen taken from the pancreas of a patient who had repeated attacks of pancreatitis for many years. Scar and edema compress a small amount of acinar tissue. B, biopsy from the same site taken four years after sphincterotomy had been performed.

4. When resistance to flow of pancreatic juice is created in any part of the duct system, including the sphincter of Oddi, enzymes freely enter the blood stream. Amylase and lipase are measurable and are an indication of the degree of resistance to flow. In severe inflammation, serum amylase levels may rise to 10 to 15 times normal.

5. The acinar pancreas, like the liver, has remarkable powers of regeneration. When destruction by disease occurs, the regenerative effort may be going on side by side (Fig. 2). Frequently, this regrowth of acinar cells can be adjudged by elevated serum enzyme levels, just as atrophy is manifest by low or absent enzymes in the blood.

6. The bile duct traverses a portion of the head of the pancreas before it joins the pancreatic duct in the ampulla. Obstructions within this portion of the pancreas can create resistance to the flow of bile. Also, the sphincter of Oddi is an influence on bile flow just as on pancreatic juice flow. It is likely that these relationships form some of the basis for the common association of diseases of the two tracts. For example, it is stated that 50 per cent of patients with inflammatory disease of the pancreas also have stones in the gallbladder.

Surgical conditions of the pancreas of importance may be considered as: 1. inflammatory (pancreatitis and its complications); 2. neoplasms; and 3. injury.

Pancreatitis occurs in all degrees of severity from mild recurrent painful episodes, which are transient, to fulminating and rapidly fatal total pancreatic necrosis. Attempts have been made to designate the stage of inflammation as edematous, interstitial, hemorrhagic, or necrotic, but the gradation from one to the other is obscure, and all variations may occur in the same individual from time to time. Pathologic descriptions of the various stages of the inflammatory reaction from edema to necrosis or fibrosis serve little purpose, since the background for all is probably the same. The process may be arrested at any stage, for a characteristic of acute episodes is rapid recovery under proper management. There is also likelihood of recurrence, added destruction, further scarring, and eventual deficiency of pancreatic external secretion.

ACUTE PANCREATITIS

Clinical Features. A typical acute attack of moderate severity begins with abdominal pain, commonly after a heavy, fatty meal. The pain is located in the upper abdomen, sometimes more prominent in either quadrant. It is sudden in onset, severe, accompanied by nausea and possibly vomiting, and frequently radiates straight through to the back.

The upper abdominal wall is held tense when palpated, and there may be tenderness over a diffuse area across the upper abdomen or in any localized segment. In very severe attacks, irritating exudate can burst into the peritoneal cavity and spread downward, so that the signs of generalized peritonitis are evident.

Fever, rapid pulse rate, increased leukocytes in the blood, and other general evidences of acute inflammation are an index of the severity of the disease. One unique event, a helpful diagnostic aid, is that the serum amylase level in the blood rises sharply at the beginning of the attack and very soon begins to decline, so that normal or subnormal levels are reached in three or four days (Fig. 3). This curve of elevated serum amylase is a reflection of the course of the episode. There appears to be an initial, sudden, and violent injury which subsides gradually unless damage to other structures ensues.

Differential Diagnosis. It is most important to distinguish between acute pancreatitis and other diseases which cause severe jolting upper abdominal symptoms because the treatment of one group is considered to be immediate operation and of the other, nonoperative management. Most often considered in the differentiation are perforation of the gastrointestinal tract and acute cholecystitis. Pain, tenderness, nausea, and vomiting may be in all instances precisely the same. Of aid are: past history of ulcerlike pain or the knowledge that an ulcer existed; plain film of the abdomen demonstrating free air in the peritoneal cavity; palpation of a distended gallbladder; serum amylase levels; and analysis of aspirated peritoneal fluid.

Serum amylase determination is such an important diagnostic measure that simple methods for rapid estimations of amylase

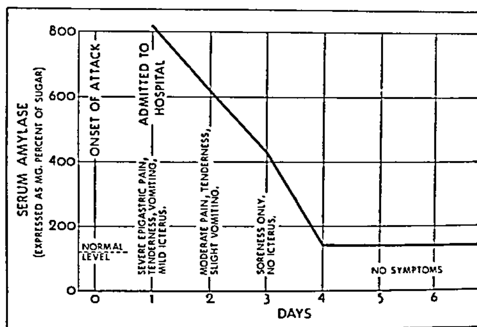


Fig. 3. Amylase levels in the blood during an acute attack of pancreatitis. This curve is characteristic. A blood sample drawn immediately after onset would probably have been much higher.

activity have been developed so that information can be available in a matter of minutes (4). The urgency of establishing a diagnosis is so great that, in occasional questionable instances, it may be advisable to explore the abdomen.

Serum amylase may be elevated as a result of diseases which permit absorption of the enzyme through the peritoneum. For instance, when a duodenal ulcer perforates and a large quantity of duodenal juice comes in contact with parietal peritoneum, amylase may be absorbed at a rate sufficient to elevate the blood level. In high intestinal obstruction with distention, intestinal contents can diffuse through the thin bowel wall into free peritoneum and promote absorption of amylase. In general, the blood level of amylase in these instances is not very high, whereas in acute pancreatitis early in the attack, the blood levels may be 10 to 15 times the normal. Aspiration of peritoneal fluid is a helpful aid in this situation. The fluid can be characterized quickly as containing bile, blood, or hemolyzed blood.

Treatment. It is generally agreed that operation for acute pancreatitis accomplishes nothing and may be detrimental. At one time it was thought that decompression of the biliary tract by draining the common bile duct or the gallbladder was helpful. Experience has shown that active, nonoperative measures can be taken which promptly reverse the chemical derangement and bring about rapid subsidence. These measures are:

1. Suppress hormonal stimulation of pancreatic secretory activity by diverting gastric acid and food from the duodenum. This is accomplished by withholding any oral intake and implanting a nasogastric tube in the stomach to aspirate all gastric juice.

2. Suppression of nervous stimulation of pancreatic secretory activity by the administration of anticholinergic drugs. In most instances, pain will rapidly subside. It is inadvisable to use morphine because it brings about contraction of the smooth muscle in the sphincter of Oddi and duodenal wall, and thus resistance to flow of bile and pancreatic juice.

The events which follow an attack of acute pancreatitis are more difficult to understand and treat. When activated pancreatic juice has spread throughout the peritoneal cavity, digestion of injured structures, erosion of blood vessels, huge fluid and electrolyte losses, and suppuration become the surgical problems. The possibilities of such complications alone or in combination are too bizarre for description. The marks left after recovery from diffuse peritoneal digestion are calcified nodules which result from fat

necrosis. At times roentgenograms will show such areas and thus indicate a previous attack of acute pancreatitis.

The most distressing feature of the disease is the high likelihood of recurrence. This is so common that one conclusion is inescapable. The disease is not accidental or fortuitous, but must be based upon a structural alteration which remains after the acute attack subsides, and is invoked repeatedly under certain conditions.

RECURRENT PANCREATITIS

The term "relapsing" is also used for this characteristic of the disease. The attacks may recur within a short period or after some years. The variability in time between attacks has led to a belief by some surgeons that removal of a diseased gallbladder will prevent recurrences. The association of the gallbladder and biliary tract affections with pancreatitis is significant; 50 per cent of patients who have pancreatitis also have stones in the gallbladder. Symptoms occurring after removal of such a gallbladder have been termed "postcholecystectomy syndrome." It is possible that in many such patients the pain was due to pancreatitis and was not influenced by removal of the more obvious gallbladder and its contained stones. Recurrence often becomes more and more frequent. After repeated injury, repair, attempts at regeneration, and dense scarring, the glands become hard, enlarged, and cylindrical in shape. It rises out of its posterior bed and may become palpable through the abdominal wall. Aortic pulsation can be transmitted through the rigid pipelike organ over a broad area in epigastrium simulating aortic aneurysm.

The end result of attack following attack for a long time is a miserable person with almost constant pain, deficient in external pancreatic secretion to a degree that normal digestion is impossible. In many, there follows diarrhea, spruelike malnutrition, diabetes (because of destruction of islet cells), and narcotic addiction. These patients are among the most difficult in all of medicine to treat.

Treatment. Many operations have been proposed and tried for this condition. Splanchnic nerve resection to interrupt afferent pathways relieves pain but will not influence the course of the disease. Total pancreatectomy, a formidable operation under the circumstances, has also been performed. The most effective and logical operations have been designed to provide free flow of bile and pancreatic juice out of a system which tends to be closed and in which bile and pancreatic juice mix abnormally. The procedures include:

1. *Section of the sphincter of Oddi* (5). Resistance to flow of bile and pancreatic juice can be shown to be created by a hypertonic sphincter muscle or one which becomes spastic for various reasons.

2. *Choledochojejunostomy* (6). In this procedure the closed system is decompressed by anastomosing the common bile duct to the jejunum. Thus, bile flow is free of sphincter resistance and cannot enter the pancreatic duct. However, pancreatic juice must still enter the duodenum against sphincter resistance.

3. *Caudal pancreaticojejunostomy* (7). The tail of the pancreas is sectioned and the main pancreatic duct anastomosed to the jejunum. This procedure is particularly adaptable to situations when the pancreatic duct is obstructed.

All these operations have, in many instances, resulted in relief of pain, regeneration of acinar tissue, and restoration of normal digestion. When the disease is advanced and scarring is so rigid that regeneration is impossible or resistance to flow of secretion is created by multiple obstructions throughout the gland, results are discouraging.

Complications of Chronic Pancreatitis. Associated with recurrence, there may be significant pathologic changes which require special consideration and treatment; they are described below.

DEFICIENCY OF EXTERNAL PANCREATIC SECRETION. Diminution and poor quality of pancreatic enzymes and bicarbonate in the duodenum produce severe gastrointestinal symptoms. Small bowel motility is increased so that food passage through the bowel is hastened and time for absorption shortened. The most prominent defect is in fat absorption. The stools are loose, bulky, foamy, and foul. Fat globules float on the surface. These

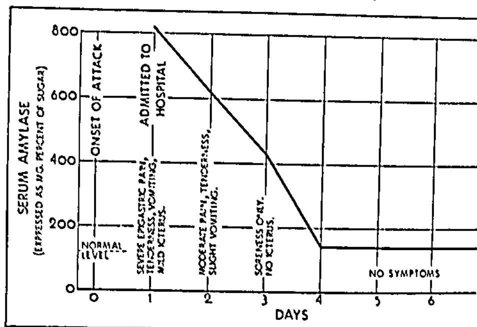


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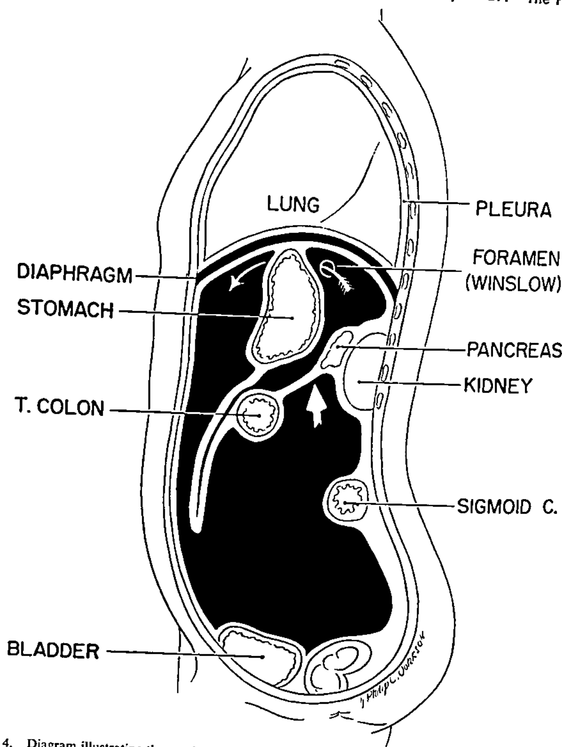


Fig. 4. Diagram illustrating the possible pathways of flow of pancreatic juice in retroperitoneal tissues. When pancreatic juice escapes into the peritoneal cavity, the most common direction of extension is directly anterior obliterating the lesser peritoneal sac and displacing the stomach forward. Pseudocysts may develop following this complication and may be found in numerous areas throughout the body, though usually attached to the pancreas.

symptoms are accompanied by lack of appetite and loss of weight. The deficiency of pancreatic secretion can be measured and the course determined by serial secretin tests (8). The method involves collection of pancreatic secretion through a nasal tube implanted in the duodenum. The hormone secretin is administered intravenously, thus giving a maximal stimulus to the gland. Volume and bicarbonate and enzyme content



Fig. 5. Pancreatogram showing a pseudocyst. Opaque material has been introduced into the pancreatic duct through a small plastic catheter (left). A dilated tortuous pancreatic duct (arrow) is outlined coursing to the tail of the pancreas where a ruptured duct allows the material to flow ino a huge pseudocyst (right).

are measured. Substitution treatment by feeding a potent pancreatic extract will ameliorate the symptoms.

PSEUDOCYSTS. When, in the course of inflammatory disease, a large duct ruptures, the resistance to flow through the tear in the duct is less than that created by the sphincter of Oddi. Under normal stimulation of pancreatic secretion by food and hydrochloric acid in the duodenum, the secretory pressure is maintained. Juice, therefore, flows out into peripancreatic spaces and continues to flow until resistance greater than that of the sphincter is met (Fig. 4). In most instances, the pathway of flow is into retroperitoneal structures anterior to the body of the pancreas. A fibrinous pseudomembrane forms in advance of the fluid, creating the appearance of a walled cyst (Fig. 5). Enlargement is gradual and progressive until a resistant structure is encountered. Most often this is the anterior abdominal wall with the stomach compressed against it. As pressures are being equalized, the patient may complain of pain after eating because of the copious flow of juice at this time. When the rupture is directed into other retroperitoneal areas, lateral or inferior, the cyst may present in the transverse mesocolon about the kidney or into pelvic structures. Unusual pseudocysts have been described traveling around to the anterior retroperitoneal spaces, between the leaves of the broad ligament of the uterus, or even upward into the mediastinum. If there is added to this abnormal flow of pancreatic juice suppuration in the pseudocyst or activation of the trypsinogen in the pancreatic juice, the seriousness of the situation is magnified.

Treatment. A time-honored operation for such a pseudocyst is anastomosis of the cyst to the gastrointestinal tract (9). Flow of pancreatic juice is then directed toward its proper goal. More logical, since the fibrinous membrane is a false one, is to decrease the resistance to flow created by the sphincter of Oddi by sphincterotomy (10). This has been shown to bring about collapse of pseudocysts. Other operations described as "marsupialization," which means simple drainage to the outside, are temporizing procedures which may result in permanent fistula.

CALCIFICATION OF THE PANCREAS. A little understood complication of pancreatitis is the deposition of calcium carbonate in the

finer acini. This precipitation has been noted to occur in a very short period of time and is striking because it may be detected by carefully taken roentgenograms. In some instances, the process is a painless one found accidentally. In most, however, it is associated with severe pain and disability. Hard, spinous, and dendritic particles of solid material clog the terminal ducts and occasionally break off to lodge in the main duct, there producing partial obstruction and painful distention. Treatment is directed toward the basic pathologic process, pancreatitis (11).

TUMORS OF THE PANCREAS

There are two important groups of tumors which occur in the pancreas. One group stems from islet cells and are largely benign. Surgical interest is centered about those which produce internal secretion at a steady or increased rate and therefore create metabolic disturbances. These functional adenomas are discussed in Chapter 39. The other group arises from acinar or duct cells and are mostly malignant.

Carcinoma. The distressing feature of this group is the almost complete hopelessness for cure in spite of well-conceived and technically feasible operations for removal of the tumor. Most arise in the head of the gland where, although the cancer may be relatively small, the common bile duct is obstructed early and visible prominent evidence of their presence is manifested by jaundice. The jaundice is obstructive, the stools acholic, and the gallbladder is distended early. In the Whipple operation, either the head of the pancreas or the whole gland is removed with the duodenum, lower bile duct, and regional lymph nodes. Reconstruction of the gastrointestinal tract, anastomosis of the bile duct and pancreatic duct, if some pancreas remains, to a jejunal limb is carried out, and the functional result is good. The survival time, however, after such successes is little longer than when a palliative anastomosis between bile duct and gut is performed to relieve jaundice. When, less frequently, the cancer arises in the body or tail of the pancreas, it produces few signs or symptoms until it has grown out of the gland itself and pain follows involvement of nerves along the posterior abdominal wall. Prior to such spread, the only manifestations of the tumor are loss of weight and loss of appetite. Early detection is difficult.

Many attempts to devise a method of visualizing the pancreas by x-rays have been made. Most efforts are designed to utilize the normal role of the pancreas in concentrating certain metals, e.g., zinc and copper, within its structure. Molecules containing iodine and zinc have been compounded and investigated, but not perfected for use.

It is probable that the discouraging course of pancreatic cancers is related to the rich lymphatic drainage of the gland directly into large collecting channels, the cysterna chyli and thoracic duct. The portal vein arises by junction of the splenic and superior mesenteric veins practically within the substance of the gland. This means that vascular spread of cancers to the liver is also an early event.

A rare, more hopeful malignant tumor, *cystadenocarcinoma,* is occasionally cured by operation. It results from malignant change in an equally rare benign cystadenoma, also cured by operation. It is detected by its large size as a palpable mass or by pressure on other organs.

Cysts. Other affections of the pancreas of surgical interest are cysts. These are frequently referred to as "true cysts," to distinguish them from the much more common pseudocysts. True cysts have an epithelial lining derived from ducts. They arise most frequently in the head of the gland and manifest themselves by their size through pressure on other nearby organs. Successful treatment is anastomosis of the lining secreting epithelial layer to the gastrointestinal tract.

ANNULAR PANCREAS

This is a developmental defect wherein a segment of the primitive ventral lobe persists anterior to the duodenum. Growth and rotation of the duodenum result in constriction by the fixed ring of pancreatic tissue and partial duodenal obstruction with enlargement of the first portion. It is important because surgical treatment should not be the very inviting maneuver of section of the ring of pancreatic tissue. Duct structures course through the ring, and the danger of leakage

of pancreatic juice after manipulation is grave. A simple anastomosis of the dilated first portion of the duodenum to a nearby loop of upper small bowel is effectively curative.

BLUNT INJURY TO THE PANCREAS

In blunt trauma to the abdomen, such as blows, kicks, and automobile accidents, the pancreas is a vulnerable organ. It may be split directly across in front of the vertebral column or partially split, with rupture of a large duct. The dynamics of flow of juice as described in the discussion of pseudocysts operates here. The difference is that pancreatic juice in the case of trauma is from a normal gland and the enzymes are inactivated and, therefore, less injurious. The manifestations of this rupture of the gland are related to the loss of pancreatic juice, which is a severe electrolyte drain, and fluid collecting in the peritoneal cavity. Retroperitoneal spread, as in pseudocysts, is also a feature when the anterior peritoneum over the pancreas remains intact. Principles of treatment are those used in pseudocyst following pancreatitis.

POSTOPERATIVE ACUTE PANCREATITIS

A rare but distressing complication following operations performed on structures other than the pancreas is fulminating severe hemorrhagic and necrotizing pancreatitis. This disaster is noted to occur most frequently when the operative procedure is on structures adjoining the pancreas and in which there is some likelihood of injury to pancreatic ducts. That this is not the whole story is attested by the same occurrence after operations performed some distance away, notably on the prostate gland. The timing of the onset and its suddenness would indicate that preoperative and postoperative starvation, with cessation of pancreatic juice flow and consequent concentration of enzymes in the acini, is a factor. Use of morphine in the postoperative period causes prolonged smooth muscle spasm, then oral feedings after starvation create a powerful stimulus to flow of concentrated pancreatic juice against resistance. Treatment of this complication is based on early recognition and is as described under acute pancreatitis.

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finer acini. This precipitation has been noted to occur in a very short period of time and is striking because it may be detected by carefully taken roentgenograms. In some instances, the process is a painless one found accidentally. In most, however, it is associated with severe pain and disability. Hard, spinous, and dendritic particles of solid material clog the terminal ducts and occasionally break off to lodge in the main duct, there producing partial obstruction and painful distention. Treatment is directed toward the basic pathologic process, pancreatitis (11).

TUMORS OF THE PANCREAS

There are two important groups of tumors which occur in the pancreas. One group stems from islet cells and are largely benign. Surgical interest is centered about those which produce internal secretion at a steady or increased rate and therefore create metabolic disturbances. These functional adenomas are discussed in Chapter 39. The other group arises from acinar or duct cells and are mostly malignant.

Carcinoma. The distressing feature of this group is the almost complete hopelessness for cure in spite of well-conceived and technically feasible operations for removal of the tumor. Most arise in the head of the gland where, although the cancer may be relatively small, the common bile duct is obstructed early and visible prominent evidence of their presence is manifested by jaundice. The jaundice is obstructive, the stools acholic, and the gallbladder is distended early. In the Whipple operation, either the head of the pancreas or the whole gland is removed with the duodenum, lower bile duct, and regional lymph nodes. Reconstruction of the gastrointestinal tract, anastomosis of the bile duct and pancreatic duct, if some pancreas remains, to a jejunal limb is carried out, and the functional result is good. The survival time, however, after such successes is little longer than when a palliative anastomosis between bile duct and gut is performed to relieve jaundice. When, less frequently, the cancer arises in the body or tail of the pancreas, it produces few signs or symptoms until it has grown out of the gland itself and pain follows involvement of nerves along the posterior abdominal wall. Prior to such spread, the only manifestations of the tumor are loss of weight and loss of appetite. Early detection is difficult.

Many attempts to devise a method of visualizing the pancreas by x-rays have been made. Most efforts are designed to utilize the normal role of the pancreas in concentrating certain metals, e.g., zinc and copper, within its structure. Molecules containing iodine and zinc have been compounded and investigated, but not perfected for use.

It is probable that the discouraging course of pancreatic cancers is related to the rich lymphatic drainage of the gland directly into large collecting channels, the cysterna chyli and thoracic duct. The portal vein arises by junction of the splenic and superior mesenteric veins practically within the substance of the gland. This means that vascular spread of cancers to the liver is also an early event.

A rare, more hopeful malignant tumor, *cystadenocarcinoma,* is occasionally cured by operation. It results from malignant change in an equally rare benign cystadenoma, also cured by operation. It is detected by its large size as a palpable mass or by pressure on other organs.

Cysts. Other affections of the pancreas of surgical interest are cysts. These are frequently referred to as "true cysts," to distinguish them from the much more common pseudocysts. True cysts have an epithelial lining derived from ducts. They arise most frequently in the head of the gland and manifest themselves by their size through pressure on other nearby organs. Successful treatment is anastomosis of the lining secreting epithelial layer to the gastrointestinal tract.

ANNULAR PANCREAS

This is a developmental defect wherein a segment of the primitive ventral lobe persists anterior to the duodenum. Growth and rotation of the duodenum result in constriction by the fixed ring of pancreatic tissue and partial duodenal obstruction with enlargement of the first portion. It is important because surgical treatment should not be the very inviting maneuver of section of the ring of pancreatic tissue. Duct structures course through the ring, and the danger of leakage

in a prompt and marked decrease in the platelet count of the recipient, suggests that autoantibodies are formed by the spleen. The various disease entities resulting from hypersplenism form the most common indications for splenectomy.

Anomalies. Congenital anomalies of the spleen are extremely rare and, for practical purposes, are limited to the relatively frequent finding of accessory spleen. The accessory spleen is a separate encapsulated mass of splenic tissue which is found most commonly in the hilum of the spleen, in the splenic pedicle, or in the tail of the pancreas but also occasionally in gastrosplenic and gastrocolic ligaments and rarely in areas more distant from the spleen. From one to five of these collections of exsplenic tissue have been noted in from 18 to 30 per cent of patients undergoing splenectomy. It is important to find these accessory spleens, particularly during splenectomy for hypersplenism, since unremoved splenic tissue may lead to a recurrence of the hypersplenism. Occasionally, abnormal locations of the spleen are noted but for the most part these are limited to those cases in which there is a generalized visceroptosis.

HYPERSPLENISM

Hypersplenism is a hyperfunction of the spleen, whereby one or more elements of the peripheral blood is decreased because of the splenic overactivity. Regardless of the mechanisms involved in hypersplenism, the decrease in peripheral blood elements delineates several clinical diseases in which splenectomy is usually indicated. These disease entities include thrombocytopenic purpura, hemolytic anemia, neutropenia, and pancytopenia which must be proven of splenic origin. Other causes of these cytopenias must be ruled out by exclusion and the bone marrow should be hyperactive for the specific element or elements which are decreased in the peripheral blood if splenectomy is to give good results.

Hypersplenism is further divided into primary and secondary forms. *Primary hypersplenism* denotes that the spleen is overactive but there is no other associated disease process. The specific clinical syndromes include essential (idiopathic) thrombocytopenic purpura, congenital hemolytic anemia, primary splenic neutropenia, and primary splenic pancytopenia. Splenectomy will give excellent results in these cases and carries a low mortality. *Secondary hypersplenism* differs from the primary form in that the splenic overactivity is due to another disease process which involves the spleen and other reticuloendothelial organs. *The diseases with which* hypersplenism is most frequently associated are leukemia, Hodgkin's disease, lymphomas, Banti's disease, tuberculosis, Boeck's sarcoid, and Gaucher's disease. In these patients, splenectomy will often greatly improve the hematological status of the patient but does not affect the course of the primary disease process.

Results of splenectomy are much better in primary hypersplenism, but it is now known that good results can be achieved in secondary hypersplenism. For example, Zollinger and Williams (5) report 91 per cent good results in primary hypersplenism and 64 per cent good results in secondary hypersplenism, following splenectomy. In their series, the postoperative mortality rate for the former group was 1.1 per cent and 13 per cent for the latter group.

HEMOLYTIC ANEMIA

The most common indications for splenectomy are the several types of hemolytic anemia. Primary hemolytic anemia is more commonly called congenital hemolytic anemia (or congenital hemolytic icterus) and has a familial occurrence. It is characterized by spherocytosis with decreased resistance of red cells to hemolysis. Secondary hemolytic anemia develops as a complication of another systemic disease process, and there may be noted no change in the red cells on routine peripheral smears. A third type of hemolytic anemia is called acquired hemolytic anemia. A family history is lacking, spherocytosis is uncommon, and no other systemic disease need be present. The cause of this form of hemolytic anemia is not always discernable. Autohemolysins and autoagglutinins play a part in the hemolysis as evidenced by the response in many cases to corticosteroid therapy. Splenectomy also gives variable results, probably because the spleen is only a part of

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THE SPLEEN

Robert M. Zollinger and Roger D. Williams

Although the spleen is not necessary to life, it is associated with numerous diseases, many of which are so serious as to threaten life. Splenic tissue represents a major component of the reticuloendothelial system. Because of its size and vascularity it furnishes a major portion of the venous blood collected through the portal system. This organ is not only often involved with abdominal trauma but also plays an important part in disease processes involving the whole reticuloendothelial system or the liver.

Anatomy. The location of the spleen beneath the left diaphragm, protected by the lower costal margin, makes its palpation difficult unless a significant enlargement has occurred. The spleen usually weighs less than 200 grams. It lies closely attached to the greater curvature of the fundus of the stomach. Two concave medial surfaces border upon the stomach and left kidney, and a single convex lateral surface is often attached in varying degrees to the leaf of the left diaphragm. The blood supply is through the splenic artery which arises from the celiac artery and courses in an irregular fashion just above the more straight vein along the superior border of the pancreas. Several branches develop near the hilum, the most significant of which are the left gastroepiploic and the vasa brevia that form collaterals between the spleen and the stomach.

Functions. The *normal* functions of the spleen are of little real significance since only temporary leukocytosis, thrombocytosis, and erythrocytosis follow its removal. Like other portions of the reticuloendothelial system, the hemoglobin of destroyed red blood cells is converted to bilirubin and often much iron is stored in the spleen. Lymphocytes, monocytes, and some antibodies are formed by the spleen, but these functions are readily assumed after splenectomy by the remaining reticuloendothelial organs. The reservoir function of the spleen in some other mammals is apparently not of clinical significance in man.

The *abnormal* functions of the spleen are of more clinical significance. Overactivity of the spleen, which has been called *hypersplenism,* results in a decrease in the peripheral blood of the platelets, red cells, white cells, or of all three of these elements. The bone marrow also shows changes, usually a marked overactivity in the production of one or more of the cellular elements. There is evidence that three mechanisms may play a part in this splenic hyperfunction: 1. Increased splenic phagocytosis and cellular destruction (Doan and associates, 1); 2. the liberation of humoral factor from the spleen, affecting the bone marrow (Dameshek and associates, 2); and 3. the formation of antibodies by the spleen, which affects the destruction of the peripheral cellular elements (Evans, 3 and Harrington, 4). The demonstration by Harrington and associates (4) that transfusion of blood from patients with thrombocytopenic purpura to normal individuals results

thelial system. Spherocytosis and increased hemolysis in saline are not found, but the bone marrow must be active for good results to be obtained by splenectomy. Removal of the spleen does not affect the course of the primary disease but often produces dramatic hematological results.

Acquired Hemolytic Anemia. This form of hemolytic anemia differs in several ways from primary (congenital) and secondary hemolytic anemias. The familial tendency is absent. The osmotic fragility of the red cells is not significantly changed and the survival time of red cells transferred to a normal person is normal (100 to 120 days).

Loutit and Mollison (6) were perhaps the first to prove the difference between the hereditary and acquired types of anemia; they found that transfusion of red cells from patients with hereditary anemia into normal recipients survived only 20 to 50 days, whereas erythrocytes from patients with acquired anemia transfused into normal recipients survived the normal length of time, i.e., 100 to 120 days. The factors responsible for increased hemolysis may be multiple. Although no other chronic systemic disease is present with acquired hemolytic anemia, hemolysis may begin as a result of exogenous hemolysin. When no cause for the increased hemolysis can be found, the hemolytic anemia may be called idiopathic acquired hemolytic anemia. In other cases, autoantibodies, autohemolysins, isohemolysins, and autoagglutinins may be discovered by special immunoserological studies.

The symptoms do not differ greatly from those of primary congenital hemolytic anemia but are more apt to occur later in life and to be more severe. Spontaneous recovery occasionally occurs, a phenomenon not encountered in primary hemolytic anemia The spleen is not as enlarged but is palpable in over half the patients. The Coomb's human serum antiglobulin test, which is positive for autoagglutinins in acquired hemolytic anemia, is the best diagnostic test.

The results of splenectomy are variable, only 50 to 65 per cent of patients having a good hematological response. This may be due to the fact that the spleen is often only one of several factors in the causation of hemolysis and the remainder of the reticuloendothelial system can perpetuate the hemolytic process. Many patients will give excellent temporary or even permanent remissions after the use of corticotropin (ACTH) or cortisone. Even when these drugs fail to give a satisfactory remission, steroid therapy after splenectomy may give good results. If splenectomy is advised, blood transfusions should be deferred until after the splenic artery has been ligated because of the danger of producing a hemolytic crisis. If the patient has been receiving steroid therapy before surgery, even though it may have been discontinued for several months, cortisone should be given on the day of surgery and for *several* days thereafter.

PRIMARY THROMBOCYTOPENIC PURPURA

Primary (essential or idiopathic) thrombocytopenic purpura is a common indication for splenectomy. The usual manifestations of this disease are bleeding from the mucous membranes, body orifices, or into various organs, including the skin and subcutaneous tissue. The disease is more common in children and young adults. The possible etiologies for the peripheral thrombopenia have been mentioned (hypersplenism). The studies of Harrington and associates who have noted thrombopenia in normal patients following the transfusion of citrated blood from patients with thrombocytopenic purpura, are interesting.

The platelet count drops from normal of 300,000 to 400,000 down below 100,000 and occasionally below 10,000 per cubic millimeter. Thrombopenia alone, however, does not produce all the signs and symptoms seen with thrombocytopenic purpura. The bleeding time is prolonged but the clotting time is unaltered. The clot which forms in a test tube fails to contract. There is increased capillary fragility, which is an important factor in the causation of purpura. The prothrombin time is usually normal, but prothrombin consumption is increased.

An anemia develops which varies in severity with the amount of blood lost and, when severe, is associated with the appearance of nucleated erythrocytes. The bone marrow shows a myeloid, erythroid, and

the reticuloendothelial system involved in this type of hemolytic anemia.

Diagnosis. The hemolytic anemias involve a differentiation of the various causes of anemia and jaundice. Hemolytic anemia should be suspected as the cause of jaundice when anemia is noted or there is a familial history of anemia and jaundice. The spleen is enlarged, chills and fever may occur with a rapid increase in jaundice with pain in the upper abdomen (hemolytic crisis), there is an absence of bile in the urine, and the indirect van den Bergh is elevated without an elevation of the direct van den Bergh. If hemolytic anemia is considered as a cause of jaundice, its differentiation from hepatocellular and extrahepatic (obstructive) jaundice is usually not difficult.

Hemolytic Crisis. Hemolytic crisis is a severe exacerbation of symptoms occurring in any of the forms of hemolytic anemia. There is a rapid breakdown of red cells, jaundice and anemia develop, often being associated with fever, nausea, vomiting, and abdominal pain. The spleen is enlarged and tender. This complication represents one indication for immediate splenectomy. Because of the danger of precipitating a hemolytic crisis, blood transfusions are usually contraindicated in patients with hemolytic anemia until after the splenic artery has been ligated.

Primary (Congenital) Hemolytic Anemia. Congenital hemolytic icterus is one of the most common indications for splenectomy. The clinical features of this form of hemolytic anemia are anemia with spherocytosis of the red cells and jaundice without bile in the urine. A familial tendency is helpful in suspecting the diagnosis but symptoms vary widely with the severity of the disease. While one member of a family may have all the classical symptoms including splenomegaly, another may have only mild anemia with no complaints. This disease most often makes its appearance in early life, but the wide variation in severity of symptoms may delay diagnosis as late as the fifth decade. The symptoms in more severe cases include weakness, a dull discomfort in the upper abdomen, splenomegaly and splenic tenderness, and jaundice. Hemolytic crises may be severe.

The diagnosis is dependent upon a familial history of anemia, peripheral spherocytosis, and an erythroid hyperplasia of the bone marrow. Although excessive urobilinogen is found in both urine and feces, due to the increased formation of bile from an increased red cell hemolysis, bile does not pass into the urine (acholuric jaundice). The red blood cells are small and ovoid with an increased susceptibility to hemolysis in salt solutions which do not usually cause hemolysis of normal blood cells (i.e., normal hemolysis begins in 0.5 per cent saline but the cells of patients with congenital hemolytic anemia may begin at concentrations as high as 0.65 per cent). Because of the more rapid breakdown of red cells there is a compensatory hyperplasia of the bone marrow. This is exhibited peripherally by a reticulocytosis, with the reticulocyte count rising as high as 20 per cent.

The diagnosis should not be confused with other causes of jaundice. Anemia is more severe than that usually seen with either hepatitis or obstructive jaundice. Liver function is normal. Absence of bile in the urine and failing to note a yellow foam should suggest the need for ascertaining a familial history and obtaining more hematological evaluation. The frequent occurrence of pigment-cholesterol gallstones may suggest the possibility of obstructive jaundice due to a stone, but with hemolytic anemia there is marked splenomegaly and an absence of biliary pain.

Splenectomy is indicated in patients with primary hemolytic anemia and gives excellent results. Although the spherocytosis continues, hemolysis is stopped in over 95 per cent of patients after removal of the spleen.

Secondary Hemolytic Anemia. This is a form of secondary hypersplenism in which hemolytic anemia develops during the course of another chronic disease process. The spleen is usually enlarged. Since patients with lymphoma, leukemia, and other debilitating diseases are those in whom secondary hypersplenism most often occurs, the diagnosis is not often confused with primary hemolytic anemia. The anemia occurs in patients in an older age group. The symptoms may be similar to those of primary hemolytic anemia but more often they are overshadowed by those of the primary chronic disease. The diagnosis should be suspected when anemia becomes difficult to control in the various chronic systemic diseases affecting the reticuloendo-

thelial system. Spherocytosis and increased hemolysis in saline are not found, but the bone marrow must be active for good results to be obtained by splenectomy. Removal of the spleen does not affect the course of the primary disease but often produces dramatic hematological results.

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TABLE 1. Types of Disease for Which Splenectomy Was Performed at Illinois Research Hospital 1936 to 1954
(Modified from Cole, et al. Arch. Surg.)

Disease	Number of Cases	Results: Good	Results: Fair	Results: Poor	Operative Deaths	Comment
I. Hemolytic Anemia	54					
A. Hereditary	40					
1. Spherocytic	33	32 (97%)	1	..	..	
2. Nonspherocytic	3	3	..	..	..	
3. Mediterranean	1	1	..	..	..	
4. Sickle Cell	1	..	1	..	..	
5. Ovalocytosis	1	1	..	..	..	
6. Congenital Porphyria	1	1	..	..	..	
B. Acquired	14					
1. Idiopathic With or Without Hemolysins or Agglutinins	8	3 (37.5%)	2	2	1	1 postop. death, hemolytic crisis
2. Symptomatic						
A. Myeloid Metaplasia of Spleen	1	..	..	1	..	Died of pericarditis 3 mo. after operation
B. Lymphoma	3	1	..	2	..	2 already dead
C. Leukemia	2	1	..	1	..	1 dead 1½ yr. after operation; other alive at 6 mo.
II. Thrombocytopenic Purpura	41					
A. Idiopathic	35	31 (88%)	3	..	1	1 patient died 20 hr. after operation; she was bleeding for 4 or 5 days before splenectomy, which failed to stop the hemorrhage
B. Secondary	6	3	1	1	1	
III. Hypersplenic States	35					
A. Primary Splenic Neutropenia and Pancytopenia	4	4	..	..	..	
B. Secondary						
1. Banti's Syndrome (Congestive Splenomegaly)	22	4 (19%)	3	10	5	8 of the 17 patients surviving operation have died—7 of hemorrhage from esophageal varices
2. Felty's Syndrome	8	4 (50%)	2	1	1	
3. Gaucher's Disease	1	1	..	..	..	Patient is alive and well 6 yr. after splenectomy
IV. Hypoplastic Anemia Associated With Celluar Bone Marrow	2				1	1 patient died of pericarditis 3 mo. after splenectomy; the other died 11 days after operation of cerebral hemorrhage with no clinical response to splenectomy

V. Miscellaneous	5					
A. Congenital Splenic Cyst	2	2	..	..	..	
B. Aneurysm of Splenic Artery	1	..	1	..	..	Developed cirrhosis
C. Splenic Infarcts (Endocarditis)	1	1	..	..	..	
D. Splenomegaly and Anemia of Unknown Cause	1	1	..	..	..	
Total	137					

megakaryocytic hyperplasia. Leukopenia is not common in this disease and, if present, should suggest atypical leukemia or aplastic anemia for which, of course, splenectomy is not indicated. The spleen is rarely enlarged; splenomegaly should suggest that the purpura is due to another disease.

ACTH and cortisone are effective in decreasing symptoms and in some patients actually produce a remission; however, this remission is usually of short duration. Accordingly, these drugs are most useful in preparing the patient for splenectomy. This is particularly true since the beneficial effect of a second course of steroid therapy is not as marked as the first. Ultimately, following several courses of therapy, the steroids become ineffective, except in the occasional mild case which may sustain a prolonged remission. Results following splenectomy for idiopathic primary thrombocytopenic purpura are good to excellent in about 85 per cent of cases (Table 1). Following splenectomy or steroid therapy, bleeding usually ceases even in those cases where there is little rise in the peripheral platelet counts.

SECONDARY THROMBOCYTOPENIC PURPURA

Thrombocytopenic purpura may develop during the course of a number of chronic systemic disease processes (secondary hypersplenism). The signs and symptoms are similar to those of primary thrombopenic purpura, but the patients are usually more seriously ill and suffer the additional symptoms of their primary disease. The spleen is usually enlarged. Occasionally the spleen is removed with a preoperative diagnosis of primary thrombopenic purpura and, after examination of the spleen and sections of abdominal lymph nodes or the liver, another systemic disease is discovered, changing the diagnosis to secondary thrombopenic purpura. Secondary purpura due to hypersplenism should be differentiated by history and bone marrow studies from purpura due to toxic substances. In the latter cases, the bone marrow is hypoplastic and splenectomy will be of no value. Until a few years ago it was thought that splenectomy was not indicated in secondary purpura. However, in 10 patients with secondary purpura, Elliott and Turner (7) reported complete arrest in six and fair results in three. All of these had a low platelet count. Steroid therapy may be required postoperatively in an occasional case or when the platelet count is not promptly elevated.

Role of Steroid Therapy in the Treatment of Splenic Diseases. Steroids (ACTH or cortisone) are very useful in the treatment of many splenic diseases but should be used primarily in the preparation of patients for operation. They have a beneficial effect in the hemolytic anemias and purpuras. Their mechanism of action is not fully understood. In the hemolytic anemias, the benefit is obtained presumably through one of two mechanisms: either the steroid affects the red cell in such a way that the antibody cannot attach itself to the cell, or it has a neutralizing effect in the source of the antibodies. Steroids are most effective in the acquired types of hemolytic anemias. They are effective in the hereditary type only when there is an associated acquired component; Cooley's (Mediterranean) anemia is an example of hereditary anemia which occasionally is benefited by steroid therapy. Benefit is sustained in both types of purpuras, but it is more marked in the idiopathic type possibly because in this

type, circulating antibodies are more common (perhaps 50 per cent). Steroids are of benefit in purpura of childhood, but even without this therapy, purpura at this age regresses satisfactorily without splenectomy, with rare exceptions. The reaction of the various types of splenic disease to steroids regardless of the responses cannot be used as an indication or contraindication for splenectomy.

As mentioned above, steroid therapy results in benefit in several types of splenic disease, but since it is not curative, the chief value is in preparing patients for operation. Often, indeed, the patient is too ill to allow splenectomy safely. This is exemplified in patients with hemolytic crisis or severe thrombocytopenia with hemorrhage and anemia. In such patients, marked temporary benefit can usually be achieved by a course of ACTH or cortisone. However, it must be emphasized that a second course of steroid therapy will be less effective, and as the treatment is continued, the disease becomes more resistant. Accordingly, the patient with hemolytic crisis may be markedly improved with steroid therapy, but if splenectomy is not performed during the remission (when the expected mortality is practically zero), the "golden" opportunity may be missed. This is true because splenectomy may have to be performed later as an emergency for a recurrent critical state for which no medicinal therapy is effective; under such circumstances, the expected mortality rate may be very high. It must also be emphasized that, if steroids have been given preoperatively, they must be continued postoperatively: this is true even though several weeks or months have elapsed since discontinuance of the therapy.

Not infrequently steroid therapy is helpful after operation when the effects of splenectomy have been unsatisfactory. Accordingly, this phase of steroid therapy may be very important.

PRIMARY SPLENIC NEUTROPENIA AND PANHEMATOPENIA

Wiseman and Doan (8) have described a rather uncommon disease consisting of splenomegaly and leukopenia for which splenectomy is curative. This condition actually represents a selective type of hypersplenism in which only one of the cellular elements (neutrophils) is involved. The bone marrow may be normal or slightly hyperplastic. Occasionally, fever and pain in the splenic area are present. There is often an increased susceptibility to infection, and preoperative antibiotics are indicated. The disease usually leads a cyclic course. Splenectomy is considered safer when the white blood count is highest and infection less likely to develop after surgery.

If all three of the blood elements (erythrocytes, neutrophils, and thrombocytes) are involved, the condition is known as pancytopenia. Bone marrow studies show a panmyeloid hyperplasia. Pancytopenia may be primary or secondary to some other disease, such as Gaucher's or Banti's disease and leukemia. With few exceptions, an enlarged spleen is found in all patients with pancytopenia of splenic origin. Splenectomy is very effective in relieving the hypersplenism but will not alter the course of the primary disease. ACTH and cortisone are not often of much value.

FELTY'S SYNDROME

The most important manifestations of this disease are splenomegaly, chronic rheumatoid arthritis, leukopenia, and anemia. Thrombocytopenia may also be present; under such circumstances the disease may be classified as secondary pancytopenia. Occasionally, lymphadenopathy and a yellowish-brown pigmentation of the skin are noted. The bone marrow is hyperplastic with granulocytic elements predominating. Splenectomy usually relieves the pancytopenia and occasionally the arthritis is also greatly improved.

GAUCHER'S DISEASE

Gaucher's disease is a rare disease affecting the spleen secondarily and occurring most commonly in young girls. The spleen is enlarged and the lipid material (cerebroside) is present in the spleen, bone marrow, and lymph nodes. Foam cells in the bone marrow are diagnostic. Common manifestations are splenomegaly, anemia, and pigmentation of the skin. Hepatomegaly occurs late in the disease. Occasionally the splenomegaly pro-

duces pancytopenia; still less commonly, rupture of the spleen may develop with little or *no trauma.* Pressure symptoms caused by the enlarged spleen are not uncommon. Any of the complications mentioned above may justify splenectomy.

RUPTURE OF THE SPLEEN

Lacerations of the spleen are serious because the resultant hemorrhage rarely stops spontaneously. Accordingly, rupture of the spleen usually necessitates operation, indications for which may be very vague because of the difficulty of diagnosis. In a series of 102 cases reported by Terry and associates (9), about half were caused by penetrating injuries and half by nonpenetrating injuries. In a series reported by Musselman and associates (10), contusion of the chest over the spleen was noted in about half and fractured ribs on the left in about one third of the cases. Since hemorrhage is the major process involved in injuries to the spleen, the systemic manifestations of injuries will be related to blood loss producing tachycardia, drop in blood pressure, and other changes of shock as described in Chapter 13.

The symptoms and local abnormal signs of splenic rupture vary considerably. On some occasions, there is marked tenderness with a fair degree of muscle spasm in the left upper quadrant. Pain may be referred to the left shoulder as evidence of irritation of the diaphragm. This pain may at times be made to occur by placing the patient in the Trendelenberg position. On other occasions, pain is minimal and tenderness is only moderate and somewhat diffuse. Under such circumstances, evidence of loss of blood may represent the indication for operation.

A diagnostic peritoneal aspiration and abdominal x-rays should be obtained in all patients suspected of having a splenic rupture. Utilizing a small syringe and a No. 20 needle, there is little danger from aspiration in all four abdominal quadrants in doubtful cases unless intestinal distention is present. If blood is found, the diagnosis is confirmed; however, a negative peritoneal aspiration should not be considered as evidence that splenic rupture has not occurred. Abdominal and chest x-ray films may show one or more of several changes. Wang and Robbins (11) have emphasized the incidence of an abnormality of the splenic shadow, particularly an enlargement as an indication of an injured spleen. This enlargement is presumably due to blood clots surrounding the spleen. Bollinger and Fowler (12) have called attention to a shadow in the left lower thorax in patients with an injured spleen. Elevation of the left diaphragm, separation of the gastric and colon gas shadows with serration of the gaseous shadow along the greater gastric curvature, and absence of psoas shadows may occasionally be noted.

Delayed rupture, with signs manifested 48 or more hours after injury, is not uncommon. The mechanism of delayed rupture is probably either renewed hemorrhage after temporary tamponade by omentum or surrounding structures or subcapsular hemorrhage which later ruptures the capsule. In the series by Terry and associates (8), 11 per cent were delayed splenic ruptures. As a consequence, patients with abdominal injury must be observed rather carefully for several days to discover the early manifestations of blood loss.

The treatment for rupture of the spleen is splenectomy, since ligatures applied to a lacerated spleen do not control the bleeding effectively. Usually it is necessary to match the patient with several donors and administer several hundred cubic milliliters of blood rapidly to improve the patient's condition sufficiently to allow operation. If the signs of shock disappear rapidly with the administration of one or two pints of blood, delay in operation may be permissible, and, in fact, operation not performed unless local signs represent indications for celiotomy. The mortality rate from splenectomy performed for an uncomplicated rupture of the spleen obtained soon after injury is almost zero. However, complicating injuries may be extremely serious. In the series by Terry and associates (9), the mortality rate was 12 per cent for patients having blunt trauma and 25 per cent for patients having injury of the spleen due to penetrating injuries.

BANTI'S DISEASE

This disease is characterized by splenomegaly, anemia, leukopenia, and portal hypertension. The portal hypertension and changes due to hypersplenism are the usual

indications for splenectomy. The portal hypertension is due to venous portal obstruction either proximal to the liver or as a result of cirrhosis of the liver. The anemia may be due to bleeding, or all the cytopenic changes may be the result of secondary hypersplenism. The disease affects children as well as adults.

The patient commonly notices a gradually increasing weakness, anorexia, and abdominal discomfort. Pallor is noted and examination of the blood shows an anemia; but the resistance of the erythrocytes is apt to be increased. The liver may be enlarged, but as the disease progresses the liver becomes cirrhotic in most cases and ascites may develop. About 15 per cent of patients do not develop cirrhosis and the portal hypertension and splenic changes are the result of extrahepatic portal obstruction from thrombosis or congenital abnormalities of the portal system.

Upper gastrointestinal hemorrhage may be the first indication that portal hypertension exists. Considerable difficulty may be encountered in differentiating esophageal from gastric or duodenal hemorrhage. Transfusions should be started immediately, but definitive therapy will have to be delayed until the diagnosis is established. Delay is necessary because the treatment of bleeding peptic ulcer (the most common cause of gastric hemorrhage) is very different from that for bleeding varices. Important in the differentiation is the history of peptic ulcer and the presence or absence of an enlarged spleen; about two thirds of patients bleeding from a peptic ulcer will have an ulcer history, whereas about 80 per cent of patients with bleeding varices secondary to portal hypertension will have an enlarged spleen. Liver tests will also be of value since they will be normal with peptic ulcer and abnormal in the majority of patients with portal hypertension. If the diagnosis is in doubt, a barium swallow with x-ray studies of esophagus, stomach, and duodenum should be made as soon as the patient's condition will allow.

As soon as the diagnosis of bleeding esophageal varices is established, an attempt should be made to stop it by passage of a Patton (or similar type) tube into the stomach and inflation of the attached balloons to obtain pressure against the bleeding point. If utilized correctly, this tube will stop the hemorrhage unless the bleeding point is located within the stomach or in the esophagus above the larger balloon. The air pressure in the balloon is maintained, according to the directions for the type balloon used, in combination with slight traction on the tube for 24 hours, following which pressure is released to prevent pressure necrosis of the esophagus and cardia of the stomach. After release of the air in the balloon, the tube should be left in situ for 24 to 48 hours lest removal dislodge the clot. If one or two attempts to control the hemorrhage are unsuccessful, operative interference, consisting of transection of the cardiac end of the stomach (with ligation of all bleeding points and approximation of the cut ends by suture), or suture of all bleeding paints through a longitudinal incision in the esophagus may be indicated.

The patient's condition with bleeding varices is usually too critical to justify the performance of a portocaval or splenorenal venous shunt. These procedures are usually reserved for elective use after the bleeding has ceased and after the patient's condition has improved. However, if there is no history of bleeding, but hypersplenism is rather pronounced and prominent varices are demonstrated by x-ray, it may be justifiable to perform a splenectomy and splenorenal shunt. Although the results of portocaval shunt are a little better than those of splenorenal shunt, the latter operation is justifiable when splenectomy has to be performed because a splenorenal shunt can rarely be performed in patients who have had a splenectomy performed at a previous operation.

It should be emphasized that not all surgeons believe that the benefit obtained from a venous shunt justifies the high mortality incident to the operation. If liver function tests show significant liver damage with jaundice and ascites present, most surgeons consider a shunt operation contraindicated.

MISCELLANEOUS

Porphyria is not a disease affecting the spleen primarily but, during the past few years, good results have been reported following splenectomy (see p. 814). The etiology of this disease is unknown. *Infarcts* of the spleen, *cysts* and *tumors* of the spleen,

and *aneurysms of the splenic artery* are rare but constitute indications for splenectomy. *Mediterranean anemia* (Cooley's anemia), a chronic anemia apparently due to a defect in the formation of hemoglobin, was, until recently, not considered an indication for splenectomy. Glenn and associates (13) have shown that these patients, although not cured, may require fewer transfusions to maintain a respectable blood level after splenectomy.

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31

THE ALIMENTARY TRACT

The alimentary tract is probably more commonly the site of disease, both functional and organic, than any other system. For the sake of completeness, the entire alimentary tract (including the oral cavity, which is in part the sphere of the dental specialty), will be considered in this chapter. Several disciplines and technics are involved in the diagnosis and treatment of disorders of the intestinal tract. The use of radiology for the indirect inspection of the gut and the use of esophagoscopy, gastroscopy, and proctosigmoidoscopy for direct visualization are of obvious importance, and the pathologic examination of removed tissues is often essential. This chapter must necessarily deal with some purely medical aspects of disease of the gut as well as with those lesions which are the problem of the surgeon. While acute appendicitis, perforations, and carcinoma are primarily of surgical, sometimes urgent surgical, importance, other conditions may be either medical or surgical in nature. Indeed, many diseases, such as chronic peptic ulcer and idiopathic ulcerative colitis, straddle several fields and thus require the closest cooperation among general practitioners, internists, surgeons, radiologists, pathologists, and even psychiatrists. Often it is found that only by cooperation among the specialists thus implied will the best therapeutic program for the patient be chosen.

Because of the complexity of the problems of intestinal obstruction, this matter will be discussed in a separate chapter.

ORAL CAVITY

The mouth is the concern of general, dental, and plastic surgeons. Oral lesions are frequently but local manifestations of more widespread disease. The teeth are important contributors to the diseases of the mouth. Much of this material in this section is based on the text by McDowell, Brown, and Fryer, to which the student is referred for greater detail (1).

The Mouth. Congenital Clefts. Congenital cleft lip (harelip) and cleft palate are probably the most common severe congenital deformity amenable to surgical correction. They vary widely in degree, may occur alone or in combination, and may be unilateral or bilateral. According to Fogh-Andersen (2) this deformity is found to some degree in one of every 660 babies in the white race; certain varieties definitely follow Mendelian genetic patterns. While clefts may be produced in experimental animals by such influences as severe nutritional deficiencies, cortisonelike drugs, and certain virus infections during early gestation, it is not certain that they are identical with the human lesions (Fig. 1).

Treatment is surgical, and requires careful planning and meticulous technic in order to achieve the optimum effect both as to appearance and to speech. The lip is best repaired at about three months of age, the objective being to produce a full and loose, protruding, smooth lip, and a symmetrical yet nondrooping nostril (3). The palate is usually operated on at about 18 months of age, with the objec-



Fig. 1. Double harelip before and after operative repair. A, at four months of age just before repair of the lip. B, at one year of age; a cleft palate was repaired at this time. (St. Louis Children's Hospital)

tive of complete closure, maximum flexibility with minimum scarring, sufficient length for nasopharyngeal closure, and preservation of the muscles with the nerve and blood supply to them. In general, narrow clefts are closed earlier than 18 months and wide clefts a year or two later. Early orthodontia may be required for proper molding of the dental arch, some speech training, and limited prosthodontia for missing teeth. The better the surgical repair, however, the less will be the need for these additional services.

Other congenital clefts are rare and include the lateral facial clefts, which are oblique from the upper lip to the orbit and even within the eye, and macrostomia, which is persistence of an open cleft from the angle of the mouth toward the ear.

INFECTIONS. The mucosa of the mouth is the site of several types of inflammation called, collectively, stomatitis. Specific local agents, such as infected teeth, chemical or physical irritants, or certain bacterial or viral invaders, are usually the cause. Many are secondary to such systemic diseases as blood dyscrasias, avitaminoses, diabetes, pemphigus and other skin disturbances, virus infections, poor hygiene, malnutrition, digestive disturbances, and metallic poisoning. While Vincent's spirochetes and fusiform bacilli can be recovered from most chronic mouth ulcers, the etiological significance of them is uncertain.

Clinical manifestations vary, but consist mostly of pain, tenderness, visible lesions (macular, papular, vesicular, or ulcerative), foul breath, and systemic evidences of infection. Treatment will be effective if the underlying cause can be found and removed. Prolonged chemotherapy may be an etiological factor due to the development of resistant bacteria or the conversion of oral saprophytes to pathogens, which become virulent and attack the mucosa. Addition of an effective antibiotic, or change to another antibiotic to which the causative organism is sensitive, is often successful. Local treatment includes simple cleanliness, liberal use of warm saline, and the removal of local irritants. Strong chemicals or escharotics must never be applied. Some lesions are on the allergic basis, any may respond to cortisonelike therapy.

Thrush is a superficial infection of the mucosa occurring in infants and in the aged, especially when debilitated and in unhygienic surroundings. It is characterized by white patches which can be removed easily, exposing a bleeding surface. The fungus, *Candida albicans*, is the causative agent. Treatment is of the underlying cause, plus local use of 10 per cent glycerine or 5 per cent gentian violet and specific antibiotics (nystatin).



Fig. 2. Fig. 3.

Fig. 2. Acute dento-alveolar abscess of the upper jaw. The patient was a 40-year-old woman. The swelling began nine days previously, 48 hours after the extraction of a left upper molar which had been painful for two weeks. The abscess opened into the mouth spontaneously shortly after the above picture was taken; a large amount of greenish, foul-smelling pus escaped. (Barnes Hospital.)

Fig. 3. Acute dento-alveolar abscess of the lower jaw. One week after onset. Incision and drainage of the abscess were followed by rapid healing with no evidence of osteomyelitis.

Noma is an extremely rare progressive gangrene, usually starting about the mouth and spreading to involve the face and neck, often fatal. The etiology is unknown, but is probably a combination of two or more of such factors as acrodynia, poisoning, chickenpox, typhoid, meningococcemia, measles, blood dyscrasias, or drug sensitivities. Treatment is based on thorough investigation to find and eliminate the cause or causes. In some cases, the local lesion is widely excised by electrosurgery, with plastic repair later if the patient survives.

The Jaw. Tumors have been discussed elsewhere (p. 418). This leaves jaw infections, most of which are of dental origin.

Acute Alveolar Abscess. This lesion, often called gumboil or root abscess, follows an acute exacerbation in a chronic dental root granuloma, the portal of entry being usually a dental cavity (Figs. 2, 3). The first symptom is pain, which is boring and pounding as the infection invades the jaw bone from the tooth root out to the gum surface. There may be edema of the overlying soft tissues, extreme tenderness to percussion of the tooth, spasm of the masseter muscles (lockjaw), fever, prostration, and leukocytosis. These manifestations differentiate it from ordinary toothache (pulpitis), in which the inflammation is entirely within a tooth. Within 12 to 48 hours after the onset, an abscess usually presents at the gum surface or through the outside of the face and should be promptly opened to prevent further spread. Antibiotic and other systemic treatment should be started promptly after the onset, but the tooth should not be extracted during the acute phase for reasons mentioned below.

Pericoronitis. This term applies to an infection under the gum flap overlying a partially erupted third molar. The clinical picture is much the same as in an alveolar abscess, with even greater tendency for the infection to invade between the masseter muscles and the ramus of the mandible to form a deep jaw



Fig. 4. Acute dento-alveolar abscess followed by chronic osteomyelitis. Three lower molars had been extracted several weeks previously. The two photographs are taken four days apart before and after incision and drainage. Foul-smelling pus was evacuated containing many types of mouth organisms. (Barnes Hospital.)

abscess (see below). Here, too, the offending tooth should not be extracted during the acute phase, but chemotherapy and surgical drainage should be instituted.

JAW ABSCESS. This deep abscess in the upper neck, or around the ramus of the mandible, is usually secondary to an alveolar abscess or pericoronitis. The usual evidences of abscess are present, plus severe trismus (lockjaw), and sometimes difficulty in swallowing or breathing. Fluctuation can seldom be elicited until very late, due to the overlying muscle mass; indeed, the swelling may be stony hard. Although local manifestations may be masked or altered by chemotherapy, surgical drainage is usually indicated on about the third or fourth day after onset. Respiratory difficulty demands immediate drainage; if pus cannot be found, relief may not follow and tracheostomy may then be necessary. However, pus is usually located between the ramus and internal pterygoid, or between the ramus and masseter muscle, or in the submaxillary triangle, or in two or more of these locations. In the older literature this condition was often called Ludwig's angina, which was assumed to be a diffuse cellulitis without pus. It is probable, however, that in most instances pus was present but just was not found.

OSTEOMYELITIS OF THE JAW. Much more frequent in the mandible than in the maxilla, this serious infection is most commonly secondary to alveolar abscess or pericoronitis, especially when a tooth has been extracted during an acute phase (Fig. 4). In reality, every alveolar abscess is associated with a slight osteomyelitis, which premature extraction of the tooth may convert into an extensive bone infection. The onset of widespread osteomyelitis is heralded by a chill, high fever, extreme prostration, and delirium, including evidence of sepsis, plus an increase in all local signs. Radiological changes do not appear until two or three weeks later, after sufficient time for decalcification or sequestration has elapsed. Treatment requires complete rest, good nutrition, attention to the airways, transfusions and oxygen if needed, adequate chemotherapy, and surgical drainage of any soft-tissue abscesses. Any bone operations should be postponed until the late chronic stage, and even then is limited to removing detached sequestra. Rapid and complete regeneration of the mandible is common, even after many sequestra have been removed.

THE TONGUE. *Tonguetie*, a common congenital deformity, is due to extreme shortness of the frenum which may interfere with nursing. While the frenum is often severed, which can be done readily, it usually stretches spontaneously in a few years without treatment. In the rare cases where surgery is necessary, a plastic procedure is performed, consisting of switching flaps of mucosa.

Simple ulcers of the tongue are usually part of a general stomatitis, or due to local mechanical trauma. Any ulcer persisting more than three weeks should be biopsied to establish or exclude a more serious diagnosis. *Tuberculous ulcers* are usually deep, painful fissures and are associated with extensive pulmonary cavitation. *Syphilitic ulcers* include the chancre, mucous patch, and gumma, all of which are now quite rare. Any nodular mass in the tongue of a syphilitic should be biopsied, as carcinoma is more common than gumma in this location. *Leukoplakia* of the tongue is a firm white plaque and is a true precancerous lesion requiring removal. *Glossodynia*, or painful tongue, is a common complaint in middle aged or elderly patients. There are no local physical findings, and the situation is commonly associated with other neurosthenic manifestations, with poorly fitting dentures, avitaminoses, or derangements of the temporomandibular joint.

Lingual thyroid represents a rare type of aberrant thyroid tissue. The tumor is located at the foramen cecum at the base of the tongue. If symptoms are produced by it, excision may be indicated. However, one should first test for the presence of functioning thyroid elsewhere in the neck, which can now be readily done with scintillation counting after administration of radioactive iodine.

Tumors of the tongue include the common *squamous carcinoma*, the less common *adenocarcinoma*, and a variety of benign tumors such as *hemangiomas* and *fibromas*, which have been discussed elsewhere (Ch. 20). Diffuse enlargement of the tongue (*macroglossia*) may be seen in cretinism, or may be due to diffuse lymphangioma.

Tonsils and Pharynx. *Peritonsillar abscess* and *retropharyngeal abscess* are now rather uncommon due to the wide and early use of chemotherapy. Symptoms and signs are those of an abscess in the local area and are usually sequelae of some upper respiratory infection. In addition to local pain, the patient may be unable to swallow or to open the jaw widely and exhibit excessive salivation. Inspection will reveal a bulging of the anterior pillar with deviation of the uvula. In *retropharyngeal abscess*, there is not only difficulty in breathing and swallowing but respirations may be of the snoring type. The mouth is usually held open. Diagnosis is made by palpation and inspection of the throat. Treatment is incision and drainage with caution to avoid aspiration of pus into the lungs.

The Salivary Glands. There are three pairs of salivary glands; the parotid and submaxillary, each draining through a single duct, and the sublingual gland, draining through a series of ducts. Tumors and cysts have been considered previously (Ch. 20). Infection and obstruction will now be discussed, under two headings depending upon the presence or absence of stone.

SIALOLITHIASIS. Stones are most common in the submaxillary gland (Fig. 5) but also occur in the parotid gland. Obstructive symptoms are produced when a stone becomes impacted in the main duct and consist of painful enlargement of the corresponding gland (usually more pronounced during or after eating), and of redness of the duct opening, from which a trickle of pus can be manually expressed. Diagnosis may be confirmed by probing the duct, or by radiography. The latter, to be most accurate, requires special soft-tissue exposures on small intraoral films. If there is just one stone in the duct, surgical removal and enlargement of the duct opening are indicated. If the submaxillary gland proper is full of stones, however, with just one in the duct, surgical extirpation of the entire gland is usually advisable, in order to relieve symptoms.

INFECTIONS WITHOUT STONES. In the absence of stone, infections of the salivary gland consist of either purulent invasion of bacterial nature, or parotitis (mumps). The latter is to be differentiated from surgical parotitis, which as a third type is described separately. In *mumps* the saliva is clear though scarce, the white blood count shows a leukopenia and a shift to the right, and there is nearly always a negative past history for mumps. Associated orchitis, oophoritis, or pancrea-



Fig. 5. Obstruction of the submaxillary duct due to stone (sialolithiasis). The patient, aged 60, had been aware of a mass, more or less tender, under the left jaw for many years. It enlarged during and following meals; occasionally it disappeared entirely. A lump under the left side of the tongue was also noted; the symptoms had become more pronounced the past few months. Note the swelling under the angle of the left side of the mandible. The photograph shows the enlarged submaxillary gland, and the x-ray reveals the stone. A photograph of part of the calculus after removal is also included in the lower right hand corner of the illustration.

titis may be present. The disease is common in childhood. Pain on salivary stimulation from acid or sweet drinks or food is well known. Mumps usually infects one or both parotids, but may involve one or both submaxillary glands. The disease is transient and requires no therapy. Cortisonelike drugs are effective in controlling the complications of orchitis, oophoritis, and pancreatitis.

Purulent salivary infections are usually limited to one gland, with pus exuding from the duct. Blood counts show leukocytosis and a shift to the left. The absence of stones is confirmed by probing or by radiography. In otherwise healthy individuals, such infections are often associated with strictures or anomalies of the main or lesser ducts, which may be shown by sialography. Treatment consists of dilatation or surgical resection and plastic repair of any strictures, or, in extreme cases, of extirpation of the entire gland. Simpler measures, such as chemotherapy, repeated probing of the duct to dislodge mucous plugs, natural salivary stimulation as with citrus fruits, or artificial stimulation with pilocarpine plus manual stripping of the duct, may suffice in moderately severe cases.

Surgical parotitis is really a misnomer applied formerly to purulent parotitis without stone occurring as a postoperative complication (Fig. 6) in extremely debilitated patients. The high mortality was probable due to the low resistance of the patient to his own mouth organisms. Because of this, radical surgery was often, though erroneously, recommended. Treatment is largely prophylactic in that this infection rarely occurs in patients kept in a good general condition and given routine and adequate mouth hygiene. Chemotherapy is now quite effective. The sooner the patient can take a normal oral diet, the sooner parotitis will subside.

Mikulicz's disease, and *Sjogren's disease* are both rare and diffuse swellings of the salivary and lacrimal glands. The pathogenesis is poorly understood. In some instances they may be associated with uveitis or other eye disturbances. The disease is usually asymptomatic except for the visible and palpable chronic nontender swellings. Saliva is

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free of voluntary control. As might be expected, diseases of the esophagus produce clinical manifestations by interfering with normal deglutition. Difficulty in swallowing is called dysphagia, which varies in severity from transient interference with the ingestion of solid food to a complete inability to swallow even liquids. Complete obstruction is usually associated with regurgitation of esophageal contents, which must be distinguished from true vomiting, in which gastric content is lost. In true vomiting, the patient usually recognizes the sour taste of the gastric contents. The liquid regurgitated in esophageal obstruction may merely be swallowed saliva, or may consist of fluids taken just a few minutes before or of food eaten many hours previously. Regurgitation of food taken hours previously is particularly characteristic of fusiform dilatation of the esophagus or of the presence of a large diverticulum.

Difficulty in swallowing may be sudden or gradual. Sudden dysphagia is usually due to the immediate effects of swallowing corrosive chemicals, to bulbar paralysis, to a foreign body, to irritation by a rubber nasal tube, or acute lesions in the neck or mediastinum, such as abscess, thyroiditis, and lymphadenitis, which may involve the esophagus by contiguity. Chronic dysphagia may be produced by strictures and tumors within or by aneurysms, vertebral disease, mediastinal tumors, or other masses by pressure from without. Occasionally, dysphagia is due to paralysis of the ninth and twelfth cranial nerves. *Gradually increasing dysphagia in an otherwise healthy person, particularly in a male, is nearly always due to carcinoma.*

Special examinations are usually essential for accurate diagnosis. These special methods include (*a*) fluoroscopic and radiologic study during and after the ingestion of a barium meal and (*b*) direct inspection of the interior of the esophagus by the esophagoscope. These types of examination usually suffice to establish the diagnosis but are most effective in the hands of those expert in the use of them. On the other hand, the passage of a bougie or tube into the esophagus in a patient with dysphagia is apt to be a dangerous procedure should an acute ulceration or an aneurysm be present, and should not be performed unless such lesions are definitely excluded.

Diverticulum of the Esophagus. Also called pulsion diverticulum, this lesion is really located in the *pharynx* and is a hernial sac through the posterior pharyngeal wall, presumably due to a congenital defect (Fig. 7). *Traction diverticulum* represents a different type, small in size, and without clinical significance, being usually noted only by radiography or at autopsy. Traction diverticula are asymptomatic, usually located in the midportion, and are the result of traction by scar following an inflammatory process such as a suppurating lymph node. *Pulsion diverticulum* develops at a point just above the cricoid cartilage where the inferior constrictor fibers merge with the circular musculature of the esophagus to form the circopharyngeus muscle. The neck of the sac is thus in the mid-line, but the mass usually presents to one side or the other, nearly always the left, as it increases in size. It rarely becomes large enough to be visible as a definite swelling. Symptoms of slight difficulty in swallowing may date back to childhood. More severe manifestations, however, do not occur unless the sac attains a fairly large size and contains food which may be retained for considerable periods of time. The patient may then be conscious of peculiar sounds or slight discomfort associated with swelling. The soured or foul food retained in this diverticulum may be regurgitated. Accidental aspiration of some of the foul content of the diverticulum into the respiratory tract during sleep, or even when the patient is awake, may lead to development of lung abscesses. Finally, the sac may become large enough to produce definite mechanical obstruction, leading in severe cases to gradually increasing malnutrition. Diagnosis is usually obvious by radiographic visualization of the sac, especially in the lateral view after the ingestion of a barium meal. *Treatment* consists of surgical excision, which is now usually performed in one stage. This condition has been well reviewed and analyzed by Lahey and Warren (4).

Cardiospasm. Slight spasm of the cardiac end of the stomach is usually functional and produces only transient difficulty in swallowing related perhaps to the condition popularly known as "globus hystericus," which, however, may occur in any part of the gullet. Cardiospasm, when it is severe and of long



Fig. 6. Acute parotitis. The patient is a 35-year-old woman upon whom a rectal operation had been performed 10 days previously under general anesthesia. The swelling began on the seventh postoperative day; five days later the opposite parotid became similarly involved. The patient was treated conservatively and several days later small abscesses were incised; recovery was eventually complete.

clear. Microscopic study shows diffuse round cell infiltration with many plasma cells and eosinophiles. In syphilitics, the lesions sometimes improve on specific therapy. Since there is evidence that these lesions may be allergic, improvement may follow prolonged cortisonelike therapy.

Deep Surgical Infections. Most of these have already been discussed under the heading of jaw abscesses (see above), originating from infections of the oral cavity which have already been described. Occasionally, however, the nature of the primary port of entry is difficult to demonstrate, although careful search should always be made. The infection may be the local manifestation of agranulocytosis (agranulocytic angina) or of leukemia. These deep surgical infections usually offer no difficulty in differentiation from the more superficial infections of the neck so commonly due to skin lesions or subcutaneous lymphadenitis. Acute diffuse cellulitis of the deep tissues involving also the floor of the mouth often is called Ludwig's angina, as already described on page 124. The typical deep cervical infections are much more localized and assume a less diffuse form than Ludwig's angina, exhibiting, moreover, localized redness, induration, and often a brawny edema confined first to one side of the neck, but not infrequently spreading across the mid-line. As in other infections, systemic manifestations may accompany a local lesion which may produce pressure symptoms sufficient to embarrass respiration and require emergency tracheotomy.

Treatment is the same as outlined above for jaw abscesses. The relation between chemotherapy and surgical incision requires accurate timing, as has already been discussed.

ESOPHAGUS

The esophagus or gullet is a muscular tube concerned with swallowing, or deglutition. In the upper portion, the musculature is striated and largely under voluntary control. In the lower portion the musculature is smooth and

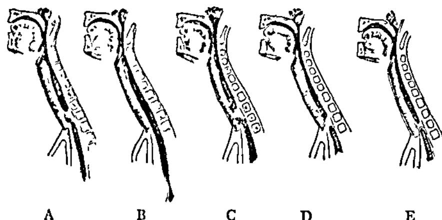


Fig. 8. Types of congenital malformation of the esophagus. A, the type in which the proximal portion ends blindly, the distal portion communicating with the trachea; this type is found in from 80 to 90 per cent of the anomalies; B, constriction without atresia, usually occurring at the distal end of the esophagus; C, communication between the trachea and each segment of the esophagus; D, communication between the trachea and the proximal segment (rare), and E, atresia of the esophagus without a tracheal fistula. (From W. H. Cole. Arch. Surg.)

available, but each requires close cooperation between the surgeon and the esophagoscopist to achieve the best results. In many instances, a functioning gullet will result, particularly if dilatation is repeated at intervals and particular attention is paid to the diet and to thorough mastication in order to avoid swallowing large particles. Eventually, the gastrostomy may be closed. In the more severe cases, an abdominothoracic operation yields the best results. Resection of the involved esophagus or a by-passing anastomosis between the stomach and the esophagus above the stricture is performed (7). The early use of cortisone to reduce the degree of scarring has been tested experimentally but lacks adequate clinical support.

Congenital stricture and other anomalies of the esophagus are rare but are apparent immediately after birth. The varieties which have been observed are shown in Figure 8. Without surgery, and even with simple gastrostomy, death may occur from inanition or more rapidly by aspiration of gastric contents into the lung because of the existence of a fistula between the respiratory and the gastrointestinal tract. Correction of the anomaly by operation is indicated and should be performed within a few hours after birth. Detailed studies and description of various surgical procedures may be found as listed in the references (8). Survival and normal development may be expected in about one third of the cases. The greatest handicap to greater success is the presence of other severe malformations. The awareness of doctors and nurses caring for newborn infants of the possibility of this condition, their alertness in recognizing the symptoms, the promptness with which patients are referred for surgery, the preoperative and postoperative care, and the technical details of the operation all play a decisive part in salvaging these patients.

Foreign Bodies in the Esophagus. A history of the accidental swallowing of a foreign body, such as a toy, can usually be obtained in this condition although, in many instances, the first intimation of trouble may be pain and inability to swallow, followed by regurgitation. If cough and respiratory disturbances occur, the foreign body is probably in the trachea or a bronchus. If the patient is seen immediately after the accident, a sedative, such as morphine, is given as soon as possible to allay apprehension and muscle spasm. After sedation of the patient, the object is frequently swallowed and reaches the stomach, where its presence may be of much less concern. Fortunately, the object is sometimes regurgitated spontaneously. If neither occurs, the child should be brought to the hospital, where a radiograph is taken in order to reveal objects which may be radiopaque (Fig. 9). If the object is sharp, the removal is urgent, lest esophageal perforation occur, with mediastinal infection as a serious complication.

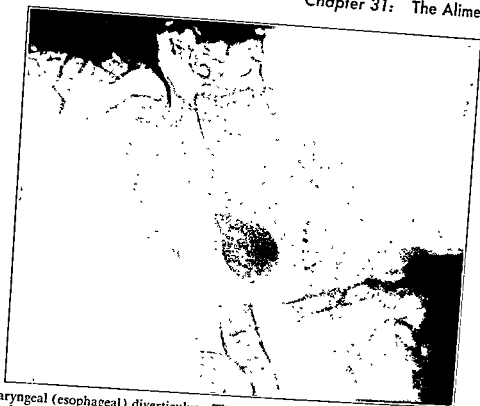


Fig. 7. Pharyngeal (esophageal) diverticulum. The roentgenogram is an oblique view after the ingestion of barium and shows the pouch well outlined. The patient, a 63-year-old male, first noted regurgitation of food following meals, especially when lying down; often a gurgling sound preceded the vomiting. Excision was performed in one stage with uneventful recovery. (Courtesy, Dr. V. P. Blair.)

standing, leads to a fusiform dilatation of the esophagus above the cardia. When long continued, dilatation may become so pronounced as to lead to retention of considerable amounts of ingested food and liquids. The patient may seem to eat and drink normally, but when regurgitation occurs it may be so profuse as to be mistaken for vomiting. Despite severe obstruction, sufficient food may still pass through to maintain the patient's normal weight. In this regard, cardiospasm stands in contrast to other types of esophageal obstruction, such as stricture and carcinoma, which lead to severe cachexia. Cardiospasm may, however, be associated with esophagitis (see below). For therapy, it must be distinguished from carcinoma and stricture which is usually possible by radiographic and fluoroscopic studies.

Treatment may be instituted from above by means of procedures designed to dilate the cardia by means of various manipulative devices, or by an operative procedure designed to divide the cardiac sphincter (Heller operation) (5, 6). In severe cases, the obstruction becomes organic and the term *achalasia* of the esophagus is often used. In such a case, more complicated and extensive abdominal or thoracic procedures may be necessary in order to relieve the obstruction (6).

Stricture of the Esophagus. Fibrous tissue may be deposited in the esophageal wall in response to previous ulceration usually due to the accidental ingestion of corrosive chemicals, the most common example of which is the swallowing of lye by young children. If the patient escapes fatal poisoning or perforation, the cicatricial contraction of the resulting scar will gradually lead to difficulty in swallowing, followed by regurgitation. Stricture formation may also follow other ulcerative lesions, such as esophagitis (see below) and carcinoma; a good history, however, will differentiate these lesions. Many patients may suffer only mild disability because of esophageal stricture; but in most instances, the dysphagia becomes severe as stenosis becomes more and more complete.

Treatment in the severe cases consists of a preliminary gastrostomy for feeding purposes, followed by gradual dilatation of the stricture. Many methods of dilatation are



Fig. 10. Carcinoma of the esophagus. The filling defect following ingestion of barium was marked in each patient; they were able to swallow liquids, but no solid food.

mucous glands. The tumor is not common, comprising only about 5 per cent of all malignant disease. It rapidly ulcerates and later, by growth or fibrous tissue contraction, produces stricture and obstruction of the lumen. The disease is far more frequent in males than in females, and in individuals of more advanced years. The tumor may occur at any level of the esophagus, but it is more common in the distal portion. Perforation may occur; metastases, unfortunately, may be widespread when the patient is first seen. The *clinical picture* is one of gradually increasing difficulty in swallowing, first of solid food and later even of liquid. Regurgitation of food and drink develops as stenosis becomes complete. Loss of weight is progressive and rapid because of starvation; pain is entirely absent. Diagnosis is made by finding a characteristic radiological picture after the ingestion of barium meal (Fig. 10) and/or by the direct visualization of the lesion through the esophagoscope. Examination of a biopsy specimen will often enable a certain diagnosis to be made.

Treatment is usually surgical. In the absence of metastases, operation should be planned for resection of the tumor, followed by primary anastomosis to restore continuity between the remaining esophagus and stomach or jejunum. In the presence of severe malnutrition, a preliminary gastrostomy or jejunostomy for feeding may be advisable. Several surgical procedures have been recommended and the choice in any case will depend on the location of the tumor. Radical resection aimed at removing all the carcinoma should be the procedure of choice and is sometimes within reach, based upon the good results reported by Sweet (15), and by others. In most cases, however, the patient is seen too late for the possibility of cure. In such cases, a palliative resection, using a plastic prosthesis has been recommended (16), but in the hands of some of us the results have been almost uniformly catastrophic because of spread of infection from the junction of plastic and esophagus. A more successful palliative method has been the placement of a plastic tube (17) through the un-



Fig. 9. Open safety pin in the esophagus. The above roentgenogram was taken immediately after admission to the hospital. The patient, a two-year-old child, had swallowed the pin a few hours previously. A few minutes after this x-ray was taken the child swallowed several times and the pin passed into the stomach (see Fig. 18).

On the other hand, the manipulations incident to removal may lead to a perforation unless performed by an expert. The use of solid food to aid the esophagus in carrying the object into the stomach may be useful in some instances, but only when there is no danger that a sharp point may lead to perforation.

Esophagitis. The lower end of the esophagus may become the site of inflammation and ulceration, leading even to fibrous stricture and stenosis, due presumably to the effect of regurgitated irritating gastric secretions. In fact, the terms reflux and peptic esophagitis are often applied (9, 10). Thus the mechanism presumably involves a relaxation of the cardiac sphincter—the opposite of cardiospasm, although the latter may occur secondarily by reflex action. Thus cardiospasm may be associated with esophagitis. However, the mechanism is far from clear even when changes in the esophagus are pronounced and the symptoms severe. A sliding hiatus hernia is often associated and is the causative factor. In a few cases, the esophagus is unusually short. The diagnosis is usually made on the basis of the history, expert radiographic study, and esophagoscopy.

The clinical picture is one of severe pain, usually substernal, and is frequently mistaken for angina pectoris. Often the pain is similar to that of gastric and duodenal ulcer in that it responds to antacid and antisecretory drugs. Obstructive symptoms occur later. In some cases, an associated duodenal ulcer is found, and adequate gastric resection leads to cure of the esophagitis, and thus emphasizes the importance of controlling acidity (10). Pyloroplasty has also been effective (11). In many of these patients, however, severe complications demand more radical procedures and several operations have been advocated (12, 13, 14). However, further study of this disease is needed.

Carcinoma of the Esophagus. Usually of the squamous cell type arising from the mucous membrane, a few of these neoplasms may be adenocarcinoma arising from the sub-



Fig. 11. Benign gastric ulcer. The patient, a man aged 58, had epigastric pain of four years' duration. Arrow points to the crater defect, which is larger than average. Gastric resection was performed.

is less clearly understood. Gastric ulcer is of special importance because it is a potential cancer, whereas duodenal ulcer has not been *observed to undergo malignant changes.* The transition from gastric ulcer to cancer has been proved in many cases, although it is likely that in most instances gastric cancer is confused with gastric ulcer because it starts as an ulcer. The possibility of cancer means that operation in gastric ulcer is more definitely indicated than as if this risk were absent, and medical therapy is potentially dangerous, as discussed below. About 15 per cent of gastric ulcers are malignant (Fig. 12). *A few (less than 5 per cent) appear to develop into carcinomas,* but proof is not definite.

Clinical Manifestations. Peptic ulcer in either the stomach or duodenum should be considered essentially as a chronic disease, with long or short periods of remission or exacerbation, even though severe acute complications may occur. Gastric ulcer, though





Fig. 12. Malignant ulcers of the stomach. Left, the x-ray defect in this patient suggested a benign ulcer; the hyperplastic area was not visible on x-ray. Right, the arrow points to the ulcer which is filled with fibrin and tumor. The crater was noted on x-ray four months ago, then disappeared (under medical treatment) as if it had healed. Nevertheless, gastric resection was performed; a typical malignant ulcer was found microscopically.

resected tumor to provide continuity for swallowing as originally suggested by Souttar many years ago. Because of the high mortality rate following resection and esophagogastrostomy for lesions in the middle third of the esophagus, some surgeons are performing the resection at one stage and the repair at a second stage, using the colon or jejunum anterior or posterior to the sternum to bridge the gap between the esophagus and stomach. Radiotherapy has also been used, particularly since the surgical results in general have proved to be disappointing. Although the benefits following x-ray radiotherapy have been disappointing, results following use of the betatron are definitely encouraging, insofar as the local lesion can be destroyed.

Gastrostomy. This procedure is necessary in esophageal obstruction, whether benign or malignant, whenever the amount of food passing through is insufficient to maintain the patient's nutrition. Gastrostomy is also sometimes indicated as a preliminary to other operative procedures, as already mentioned. If there is an esophageal stricture to be dilated, the opening is made as near the cardiac orifice as possible through a high right rectus incision so as to facilitate bouginage from the gastric side. On the other hand, if resection of a low lying carcinoma with primary anastomosis is planned, the opening is made into a more distal portion of the stomach or into the jejunum. Many types of gastrostomy have been described, but they fall into two general groups, depending upon whether the opening is to be permanent or temporary. In the latter case, a large catheter is inserted into the stomach through a small incision, and the gastric wall infolded with concentric purse-string sutures around the tube, which is brought out through the abdominal wall by a separate small incision. The Witzel technic is similar, except that the infolded stomach wall extends in linear fashion rather than concentrically. In either case the tube, when it is removed, leaves a connective tissue-lined fistula, which rapidly closes. If a permanent gastrostomy is desired, an operation of the Janeway type must be performed. In this procedure, a flap of gastric wall is fashioned into a mucosa-lined tube around the catheter, and the opening in the stomach is closed. The external end of the flap is sutured to a part of the abdominal incision, mucosa to skin. Thus there is created a short tunnel leading from the gastric lumen to the outside, lined by mucosa and easily entered with a catheter. As long as the mucocutaneous border is intact, the fistula will remain open.

STOMACH AND DUODENUM

The clinical history, examination, and usual laboratory studies will reveal the existence of surgical diseases of the stomach and duodenum. However, an accurate diagnosis is often possible only after special examinations. The most important are fluoroscopic and radiologic examinations after the ingestion of a barium meal. As with other radiologic examinations, however, this must be carried out by an expert in order to get the full advantage of the best technic. Interpretation of radiologic findings is not always easy in terms of a specific diagnosis and often involves a certain degree of both positive and negative errors. Direct visualization of the interior of the stomach by means of a flexible gastroscope may also be indicated. With these procedures, the diagnostic accuracy of gastroduodenal disease has been greatly increased, but as with other so-called laboratory procedures, must only be used in conjunction with a clinical evaluation of the patient. The tendency to rely entirely upon such special examinations is to be deplored. Test meals of various kinds to measure gastric secretory function, formerly used as routine, are now seldom employed except in clinical research. Gastric secretory activity may also be estimated by the uropepsin excretion in the urine. Gastric acidity can also be estimated by the urinary content of quinine or methylene blue which are released by ion-exchange resins containing them, following ingestion of them (so-called tubeless gastric analysis). These may prove of value for routine clinical use but as yet are mostly research tools requiring further study.

Gastric Ulcer. Most gastric and duodenal ulcers (the latter is discussed separately) are called *peptic ulcers* for reasons to be discussed below. This remarkable lesion is often located in the pyloric region or along the lesser curvature (Fig. 11). The pathogenesis, though apparently similar to duodenal ulcer,

they have a tendency to heal and recur, and occasionally to be multiple. In the simplest cases, the mucosa alone is denuded, but in more severe cases the necrosis or digestion extends more deeply, so that more of the wall becomes involved. If, in the process, a blood vessel is eroded, *hemorrhage* follows. *Perforation* of the entire duodenal wall follows when the lesion reaches the serosa. Should the ulcer be located on the posterior wall, the perforation encounters the head of the pancreas, which becomes the site of chronic induration. More commonly, however, the ulcer is in the anterior duodenal wall so that perforation reaches the peritoneal cavity, resulting in a diffuse peritonitis unless operation is promptly performed, or unless the right lobe of the liver, omentum, or gallbladder becomes adherent and seals it off, or permits the formation of a small walled-off cavity.

The propensity of peptic ulcer to undergo intermittent healing undoubtedly explains the clinical behavior in many of these patients. What probably happens is that tiny erosions or even ulcers are frequently formed in the stomach and duodenum from the mechanical effects of hard or harsh foods, or from other factors, most of which probably heal without being noticed. Even when definite symptoms are present, the frequent spontaneous remissions enjoyed by these patients indicate healing. Such a healing process has also been noted by radiologists; and surgeons have frequently seen an old scar shining through the serosa of the first part of the duodenum in patients with a previous "ulcer history." Such scar has clinical interest only in that it may be sufficient to produce an *obstruction*, which at the pylorus may lead to serious symptoms, as discussed under complications.

The *pathogenesis of peptic ulcer*, though only partly understood, is undoubtedly associated with the presence of the proteolytic ferment in the gastric juice which permits digestion of the mucosa. At least it is true that a peptic ulcer does not form in the absence of gastric juice. Moreover, gastric mucosa is always adjacent to or at least a few centimeters proximal to the site of the ulcer. This applies to marginal ulcer which, as described later, is chiefly on the jejunal side of the gastroenterostomy stoma. This is also true in the ulcers found in Meckel's diverticulum, a rare lesion which is described on page 747, which is also associated with the presence of aberrant gastric mucosa in the pouch. Finally, experimental peptic ulcer likewise occurs just beyond the secreting gastric mucosa. It appears, therefore, that not only is the proximity of gastric mucosa necessary for the formation of peptic ulcers but that they form very close to the point where secretion first comes in contact with the ulcerated tissue.

A high acidity is probably just as important if not more important than the presence of pepsin. Indeed, a high gastric acidity has long been found on examination of the gastric contents of many ulcer patients. At any given moment, however, the gastric acidity may be low or absent, even in the presence of an ulcer. Because of the wide variations normally found, measurement of gastric acidity is now seldom used in the diagnosis. Nevertheless, the beneficial effects of alkaline therapy in those patients emphasize the importance of a high gastric acidity, not only in producing symptoms of pain but also in preventing ulcers from healing. Operative procedures in general are more effective when they lead to low or no gastric acidity. It seems logical, therefore, to suppose that not only is the healing process interfered with by high gastric acidity but that high acidity favors digestion or necrosis. Much of this evidence has been summarized in detail by Dragstedt (19). Faulty regulation of gastric acidity, therefore, would seem to play an important part in the pathogenesis of peptic ulcer.

The control of gastric secretion is equally shared by neurogenic and humoral influences. The former is spoken of as the cephalic phase of gastric secretion and is mediated through the vagus nerve. The latter is called the gastric phase and resides in a hormone produced by antral cells in the distal third or half of the stomach. There is also a humoral intestinal phase, but this is quantitatively small. These factors in the control of gastric secretion and acidity are of importance in surgical therapy, as discussed below. Another secondary factor in the control of gastric acidity should also be mentioned because it may be of significance in certain cases, and that is the neutralizing effect of alkaline pancreatic juice

similar to duodenal ulcer, usually presents a less definite clinical picture. Epigastric distress or pain, while periodic and definitely related to food intake, is more likely to be variable even when severe. Ingestion of food or alkali often relieves the pain, but in some cases the former may aggravate it. Such symptoms as dyspepsia, which includes sour eructations, bloating, and heartburn are not infrequent. Vomiting is not uncommon. Diagnosis is usually readily made radiologically after a barium meal by the demonstration of a characteristic niche in the outline of the stomach. In many cases, certain manifestations enable the expert radiologist to distinguish a benign ulcer from carcinoma. There is, however, a considerable margin for error; what usually happens is that, in order to avoid the mistake of calling a malignant lesion benign, most radiologists will tend to err in the reverse direction by calling a benign lesion malignant. Even gastroscopy may fail to make a definite differential diagnosis. These considerations are important in that the clinical picture plays a lesser part in deciding the question of therapy than it does in the case of duodenal ulcer. Gastric ulcer is occasionally associated with gallbladder and appendiceal disease, and may be overlooked in the presence of them not only clinically, but also at operation. Unlike duodenal ulcer, gastric ulcer is as common in women as in men. The complications of gastric ulcer, such as hemorrhage, obstruction, and perforation, are similar to those of duodenal ulcer and will be discussed under complications (see p. 737).

TREATMENT. The therapeutic problem in gastric ulcer is dominated by the possibility that the lesion may be malignant, a diagnosis which can be made with certainty only by microscopic study after removal. For this reason, many surgeons advocate immediate operation as soon as the diagnosis is made. However, on certain occasions (e.g., young patients, acute short history), the diagnosis of benign ulcer can be made with fair certainty, and at least a trial of medical therapy for three or four weeks is justifiable. When clinical, radiologic, or even gastroscopic evidence suggests cancer, an operation should unquestionably be carried out at once; even when all evidence points to a benign ulcer, it is wiser to keep in mind the possibility that cancer may be lurking in a few such cases, as emphasized by Eusterman years ago (18). Thus, the likelihood of cancer places a grave responsibility on the physician who prescribes nonoperative therapy even if there is some radiologic sign of healing, particularly in the older age group. If medical therapy is used, the patient should preferably be under observation in the hospital and released only if the ulcer has shown unmistakeable clinical and radiologic evidence of complete healing within a two- or three-week period. Even then, subsequent radiologic examinations at intervals of three to six months are advisable, and operation should be carried out if the lesion recurs even in the absence of symptoms. Persistent pain may call for operation in any case. The difficult ulcers are those high on the lesser curvature close to the esophagus, impossible to excise short of complete gastrectomy. In such a case, control of gastric acidity by a traditional gastric resection may permit the ulcer to heal if it is benign. In all other cases, gastric resection (see below) including the ulcer, the greater omentum, and a wide area of lymphatic tissue, is the procedure of choice, lest the lesion contain malignant cells. Microscopic (frozen) section of a portion of the lesion at operation carries the danger of spread and is not advisable or necessary, in general. The complications of gastric ulcer, such as perforation and hemorrhage, are similar to those of duodenal ulcer and will be considered under that heading.

Duodenal Ulcer. The duodenum is more often the site of peptic ulcer than the stomach, in the ratio of five to one. However, the ulceration frequently occurs so close to the pyloric ring that it may be difficult to decide whether the lesion is duodenal or gastric. Ordinarily the difference is easily demonstrable at operation, since the pylorus can be located by the transverse pyloric vein. Ulcers distal to this vein are duodenal, those proximal to it are gastric.

PATHOLOGY. The location of duodenal ulcers nearly always is the first portion of the duodenum, just beyond the pyloric ring at the site where gastric contents first strike the duodenal mucosa which may be of some significance in the pathogenesis. The lesions vary considerably in gross appearance, for

than the acute phase of the disease. During the acute phase, rest in bed with the exclusion of all disturbing outside influences may be important for spontaneous healing of the ulcer.

Duodenal ulcer becomes a surgical disease primarily because of the complications, which are described below. However, elective operation is indicated even in uncomplicated peptic ulcer when symptoms persist or recur despite competent medical treatment. The success of operation under such circumstances depends upon many factors, including careful selection. Patients with a long history of vague digestive disturbances, who are neurotic, and who happen to show a duodenal deformity on one examination are not good subjects. On the other hand, those with severe disability and repeated evidence of unquestioned ulceration, and who do not wish to or cannot live on a restricted though successful dietary regimen, are, in general, apt to enjoy freedom of symptoms and to enjoy a normal dietary intake after an adequate operation.

The operation, to be successful, is one which, in general, best controls gastric acidity without postoperative symptoms. Gastroenterostomy, once the procedure of choice, is now seldom used except in poor risk patients with advanced pyloric obstruction (or in conjunction with vagotomy). While 90 per cent of patients used to enjoy immediate relief of symptoms following gastroenterostomy, the percentage rapidly dropped with the passage of time so that within five years after operation more than a third were found to be suffering from their old symptoms. In many instances, the recurrence of pain was due to the formation of a new ulcer in the jejunum just beyond the operative stoma (jejunal or marginal ulcer, which is described later).

The most commonly used operation now is partial gastrectomy, a procedure which has long been known to result in a more persistent lowering of gastric acidity than is the case following a gastroenterostomy. The Billroth II pattern may be used, in which the residual gastric pouch is anastomosed to the duodenojejunal junction to re-establish enteric continuity, and the duodenal stump at the pyloric amputation site is closed blindly, thus taking the duodenum out of the main enteric stream. Under these circumstances, the gastrectomy, to be effective, must remove all antral cells, known to produce a hormone (gastrin) stimulatory to acid secretion by the remaining portion of stomach. Antral cells extend further along the lesser than the greater curvature so that the line of resection must be at least two thirds of the distance from the pylorus to the cardia on the lesser curvature of the stomach, and well above the junction of the left and right gastroepiploic vessels on the greater curvature. In most hands this amounts to removal of approximately 75 per cent of the stomach. The gastrojejunal anastomosis may be made either antecolic or retrocolic; the latter is preferred by most who have run carefully controlled series because it permits utilization of an extremely short duodenal loop, a factor minimizing the incidence of later recurrent ulceration.

The Billroth I pattern, largely abandoned until a few years ago, is now regaining acceptance; in this operation, the remaining upper gastric pouch is anastomosed to the cut end of the duodenum or antrum, thus leaving all elements in enteric continuity. With retention of the antrum in continuity, the hormonal hypersecretion seen after the Billroth II procedure does not occur (Dragstedt, 21 and Thal, 22). There is good evidence for the production of an acid suppressing hormone by the antral cells under these conditions (23). Wangensteen (24) has adopted a sleeve resection which divides the vagi in mid-stomach and preserves the antrum, coupled with pyloroplasty to forestall the poor gastric emptying otherwise seen after vagal section. The Billroth I pattern tends to give better results in women and in thin subjects (25) and is less likely to lead to postgastrectomy dyspepsia.

Resection of the vagus nerves just below the diaphragm, as advocated by Dragstedt, is now usually performed only together with gastroenterostomy (26) or pyloroplasty (27) but neither combination has received wide acceptance.

The high mortality which followed gastric resection in the past has been steadily reduced within the past decade, due largely to more adequate preoperative preparation and postoperative care. Nutritional deficiencies are frequent in these patients as in others with

when, as, and if it enters the stomach or even in the duodenum.

Another element in the pathogenesis of peptic ulcer is undoubtedly the motor function of the stomach and duodenum. An increased gastric motor activity has actually been observed in many patients with ulcer. Presumably this enables highly acid content chemically to produce or aggravate mucosal ulceration. Spasm of the pylorus, in many instances, may interfere with adequate control of gastric acidity, diminishing the regurgitation of alkaline duodenal contents, a factor which may play an important part in the control of gastric acidity.

The autonomic nervous system, which controls both secretory and muscular activity, is therefore probably involved in the pathogenesis of peptic ulcers. Indeed, it has long been known that worry, fatigue, and tension greatly aggravate the clinical severity of peptic ulcers, presumably because of the influence of these factors on gastroduodenal secretion and motility via the autonomic nerves, particularly the vagus. This concept of autonomic derangement was advanced greatly through the well-known observations of W. B. Cannon (20). Moreover, the role of stress is indicated by recent observations showing that adrenocortical stimulation may lead to peptic ulceration.

Other etiological factors, while important, are less readily explainable. For example, ulcer symptoms are apt to be worse during the spring and fall and are aggravated by respiratory and oral infections, especially about the teeth.

CLINICAL MANIFESTATIONS. Entirely apart from the complications which are discussed separately, duodenal ulcer produces a characteristic type of upper abdominal pain varying from a sense of hunger and distress to a dull, gnawing, boring pain, which may be severe and disabling. The pain is not due to the presence of the ulcer per se, but to the spasm and cramping which are provoked. The pain is not only variable but essentially chronic, yet intermittent, and may disappear for months or years, being aggravated by the factors already mentioned above, particularly mental stress.

The pain is often described as a hunger pain because it occurs characteristically when the stomach is empty, i.e., two or three hours after meals. Moreover, it is usually relieved by eating. Patients soon learn of this and carry food with them or keep it at the bedside because of the relief it affords. Relief is also achieved by taking alkalis, but the effect is not as lasting. Other symptoms, such as heartburn and belching, usually referred to as dyspepsia, are not characteristic since they occur in many other conditions. Vomiting is frequent in the severe cases, especially when pylorospasm is persistent or actual pyloric obstruction has developed.

Abdominal examination may be entirely negative or may reveal deep tenderness in the epigastrium, presumably over the lesion. More superficial tenderness, or hyperasthesia, is due to the same mechanism which produces referred pain and can often be elicited along the costal margin. An accurate diagnosis of duodenal ulcer, however, depends in most cases upon the findings of the expert radiologist following the ingestion of a barium meal. Collection and examination of gastric contents is of value when it reveals a high acid titer, particularly in patients who also show evidence of hypersecretion. However, high acidity may be found in patients without anatomic evidence of ulcer, either radiologically or at operation. These patients, however, may suffer the same type of pain as described above, and it is usually explained as being due to pylorospasm. The more serious manifestations of duodenal ulcer are due to the complications which are described below.

TREATMENT. Medical therapy is successful in most patients with uncomplicated duodenal ulcer. Drugs are employed to decrease gastric secretion and to reduce gastric acidity. Attention must, of course, be directed toward the control of psychosomatic disorders, particularly those based on emotional strain and the stress of "high pressure" living. Dietary measures are based upon modification of the regimen popularized decades ago by Sippy and consists essentially of a bland, liquid diet usually containing a large fat (cream) content. The fat tends to slow gastric peristalsis. Unless such a diet contains sufficient protein, vitamin C, and iron, it may lead to nutritional deficits. Severe diets are, in general, losing favor in medical therapy, especially as a means of controlling more

cicatricial contracture just as peptic ulcer elsewhere.

The *clinical manifestations* of marginal ulcer are generally severe and are similar to those of duodenal ulcer, i.e., "gnawing" pain, anorexia, nausea, epigastric distress, and occasionally vomiting. The pain may be located to the left of the mid-line and may be associated with local tenderness at the same point. Should the marginal ulcer perforate into the free peritoneal cavity, sudden and acute manifestations are produced similar to those of a perforated duodenal ulcer, as discussed later. Perforation into the colon produces a gastrocolic fistula, the manifestations of which are less acute but nonetheless severe, and include great wasting, severe diarrhea, fecal vomiting, and bleeding, which may be severe. The ulcer may at times be associated with severe hemorrhage; hematemesis is not as common as tarry stools, but anemia may be prominent. Diagnosis is best made radiologically, but the ulcer can be thus demonstrated in only a little more than half the cases.

Treatment of a dietary nature, such as is used in duodenal ulcer, is tried, but operation in most cases becomes necessary sooner or later (34). The operations for marginal ulcer consist chiefly of excision of the stoma with closure of the opening in the stomach and the re-establishment of the original continuity of the jejunum, followed by the production of a new stoma or of subtotal gastric resection or bilateral vagotomy. In a few cases developing after a Billroth II operation, resection of the duodenal stump is indicated to remove antral mucosa which may have been left inadvertently. In certain cases, the cause of the persistent gastric hypersecretion and ulceration will be found in remarkable islet cell tumors of the pancreas which remain unnoticed because they do not produce hypoglycemia (Zollinger and Ellison, 35).

Complications of Peptic Ulcer. The three most important complications of peptic ulcer are perforation, severe hemorrhage, and obstruction. Hourglass stomach is rare and occurs, of course, only in gastric ulcer. Carcinoma development is a fourth complication, but is a problem only in gastric ulcers, being observed with extreme rarity in duodenal ulcers. The treatment of carcinoma complicating peptic ulcer is discussed elsewhere.

Perforation. Ulcers which perforate slowly into a solid viscus, such as liver or pancreas, tend to produce rather indefinite, though severe, local tenderness and pain of the latter, often going through to the back. More commonly, the perforation of duodenal ulcer is of dramatic suddenness, occurring practically only in males. The patient may have had previous digestive disturbances suggestive of ulcer, but frequently the perforation seems to be the first intimation of trouble. It rarely occurs while under treatment, whereas in untreated patients 20 per cent are said to perforate at one time or another. The pain is of excruciating severity and precipitates immediate prostration or collapse due apparently to the intensity of the pain. The patient lies on his side with his knees drawn up and will not move for fear of aggravating the pain. He often breaks out into a cold sweat and his brow and extremities may be covered with beads of perspiration. However, there is usually no other evidence of surgical shock, for the pulse and blood pressure are normal. In the occasional case with pronounced fall in blood pressure, the immediate prognosis is grave (J. D. Stewart). Vomiting commonly occurs. On abdominal examination one finds the most pronounced muscular rigidity, aptly called "boardlike." Moreover, the slightest pressure elicits exquisite pain, and the resistance of the spastic muscles cannot be overcome. It is most evident, however, over the right rectus, particularly in the epigastrium. The patient's face is anxious, but only because of pain. Laboratory examination reveals only a leukocytosis characteristic of peritoneal irritation. After a few hours, a radiograph taken in the upright position will in 80 per cent of cases reveal air under the diaphragm (pneumoperitoneum, as illustrated in Fig. 14). Differential diagnosis from other abdominal diseases is discussed elsewhere.

Treatment of perforation of an ulcer into the free peritoneal cavity represents a surgical emergency. Moreover, the mortality increases with the period elapsing between perforation and operation. If the patient is operated upon under two hours, mortality is very low; under 12 hours, slight; between

chronic gastrointestinal disease. Correction of deficiencies, particularly hypoproteinemia, dehydration, lack of vitamins C and B_1, has been found to lower operative risk tremendously.

The *results* of adequate gastric resection are excellent, as shown by a permanent restoration to health in up to 90 to 95 per cent of subjects. An important requirement is sufficient attention by the surgeon to psychosomatic factors, which he is often much more able to treat than the patient's own physician or even a psychiatrist. The most serious but rare hazard of gastric resection is recurrent ulcer, which is discussed below. The end results of gastric resection are occasionally marred by the variable incidence of annoying and sometimes persistent sequelae called "postgastrectomy" syndrome or dyspepsia or "dumping." These consist of a variety of symptoms including epigastric distress, flatulence, discomfort after meals followed by an empty feeling, faintness and asthenia, and failure to gain. It appears probable that these symptoms are due to rapid introduction of hypertonic fluid into the jejunum, with secondary withdrawal of huge volumes of water from the circulating blood (Randall, 28). There are other factors which contribute to the picture, including a faulty selection of patients for operation. Creation of a small gastroenterostomy stoma lessens the incidence of dumping (Waugh, 29). An important factor also is the tendency up until recently toward removal of too much stomach. In a 5- to 15-year study (30) in nearly 1,000 cases, the incidence of postgastrectomy disturbances increased strikingly as more and more stomach was removed, presumably to lower the incidence of recurrent ulcer, which, however, remained constant at 4.5 per cent. The over-all restoration to complete health in this series was 85 per cent. Everson (31) has conducted numerous animal and clinical observations determining the physiologic differences between the various operations on the stomach.

Much can be done to help most patients with symptoms of dumping. Hypnosis has been strikingly successful in some (Wangensteen, 32). Use of a solid diet containing largely meat, fish, and other protein and fat-containing food, but little carbohydrate, has been helpful in some hands. Free administration of salt-containing fluids, especially beer, in the few minutes before meals has also proved effective, presumably because it bolsters the blood volume sufficiently to minimize the systemic effects of withdrawal of large volumes into the duodenum (Poth, 33). Occasionally, operation to convert a gastrojejunostomy to a gastroduodenostomy will be successful in curing the dumping syndrome, as will also a revision of the anastomosis simply to delay gastric emptying (Poth). The tendency without operation is for the symptoms gradually to subside over a period of months.

Recurrent (Marginal) Ulcer. This distressing postoperative complication usually follows a gastroenterostomy, less frequently an adequate gastrectomy. Islet cell tumor of the pancreas may be responsible (see below). It is a true peptic ulcer whose formation, no doubt, is due to the persistence of a high gastric acidity because of the failure of the operation favorably to influence the secretory or neutralizing mechanism (Fig. 13). Such an ulcer may bleed, perforate, or lead to

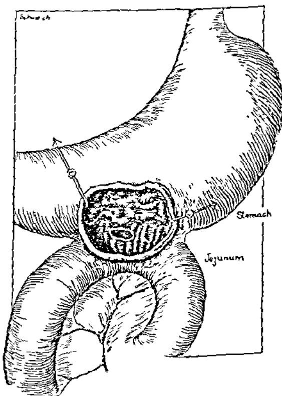


Fig. 13. Jejunal ulcer following gastroenterostomy. Ulcer is not marginal but is actually distal to the stoma and in the jejunum.

such a case, the term *massive hemorrhage* should be applied, limited, however, to patients who have lost sufficient blood (at least 1 to 2 liters) to produce an anemia of 2.5 million red cells per cu. mm. (7 grams per cent) or less, plus unmistakable signs of surgical shock, including persistent hypotension. Fatalities are, in general, limited to this category, yet really all can be prevented by adequate emergency therapy. Hemorrhage is usually evident by hematemesis, in about three fourths of the cases, but in all melena is always seen sooner or later after the bleeding.

Treatment of the mild cases presents no particular problem. Although a mild hemorrhage may produce an anemia, it does not lead to signs of shock. Threat to life is therefore practically nil, hence nearly all patients recover with or without transfusion. Massive hemorrhage, on the other hand, because of the threat to life, has always presented a difficult problem. One of the most difficult aspects of the problem is establishment of the cause of bleeding. Hemorrhagic diatheses must first be eliminated. Usually a good history and an emergency bromsulphthalein test will eliminate bleeding from esophageal varices. There remain peptic ulcer, gastritis, superficial erosions, cancer of the stomach, ulceration of leiomyoma of the stomach, and bleeding of unknown origin. Statistically, peptic ulceration is the most common of these factors. The emergency care of any patient with massive gastroduodenal hemorrhage is of great importance, regardless of the hour of the day or night; it will play a large role in determination of success. This implies thorough and repeated examination, including vital signs (temperature, blood pressure, pulse, state of consciousness, and so forth) and laboratory examinations, including hemoglobin or red cell count and, if possible, circulating red cell mass (usually by hematocrit and total blood volume determinations).

Several patterns of therapy have been recommended and have been assayed from the practical standpoint by Dennis and associates (36). In *one* the patient is transfused vigorously until out of shock or until it appears unlikely that transfusion alone will handle the shock, and subjected to operation without delay (Stewart, 37). Blood should preferably be administered until the hemoglobin level is above 10 grams per cent. The danger of transfusions is open to question, Andresen (38) being fearful, and Costello (39) not fearful if the blood is given slowly. The rate of transfusion may be fast in this pattern of management only until the blood pressure begins to approach normality.

In a *second* pattern of management (Dunphy and associates, 40), an effort is made to permit those who will do so to cease to bleed on conservative care. The thesis is that, even though the surgical mortality of those gastrectomied late after failure of conservative therapy will be higher than the surgical mortality of early cases, nevertheless so many will cease spontaneously that the over-all mortality will be lower than as if all are subjected to early operation. Rhoads (41) outlines a pattern of transfusion rates, utilizing operation at once if three units of blood fail to relieve initial shock, or if, after relief of initial shock, a slow, continuous drip of blood at the rate of one unit every eight hours fails to maintain the patient in a shock-free state.

A *third* pattern consists of extreme conservatism. This pattern was first suggested by Andresen (42), and was adopted with modifications by Meulengracht. Transfusions are feared because of the risk that the enhanced blood pressure will lead to resumption of bleeding and because of fear of loss of some clotting factors by dilution of the patient's blood with bank blood. During observation, blood is administered in amounts of 100 ml. or less, and only for air hunger or for very profound blood pressure drops, is a formula containing gelatin, milk, and added protein given at frequent intervals.

Certain factors pervade thinking in regard to management of massive gastroduodenal hemorrhage. Attention to an adequate food intake is important, particularly when the bleeding has stopped and immediate surgery is not contemplated. The empty stomach was originally assumed to be at rest, without realizing that the ulcerated stomach actually contracts much more when empty than when it contains food. Thus, starvation has harmful effects which are now well known for other reasons, although Lenhartz, as long

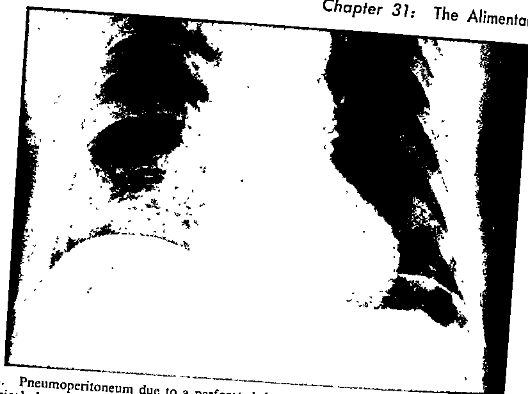


Fig. 14. Pneumoperitoneum due to a perforated duodenal ulcer. The patient, a young man aged 28, gave a typical ulcer history of several years' duration with development of severe epigastric pain six hours before admission. The x-ray reveals air under the diaphragm on each side. Operation revealed a perforation of the ulcer on the anterosuperior portion of the duodenum near the pyloric ring. Closure was effected by an omental tag. Convalescence was uneventful.

12 and 18 hours, considerable; whereas after 24 hours, the prognosis may be grave. Gastric suction and chemotherapy may therefore be justified in the late cases, but most surgeons would deny that such therapy is sufficiently safe in the early hours when the risk of operation is so low. The minimum requirement at operation is closure of the perforation. Gastric resection, however, has been carried out, and may be justified in patients with a previous gastric ulcer history, operated upon in excellent general condition within a few hours after the perforation.

HEMORRHAGE. Although hemorrhage from peptic ulcer (Fig. 15) is frequent, only seldom is it severe enough to threaten life. In

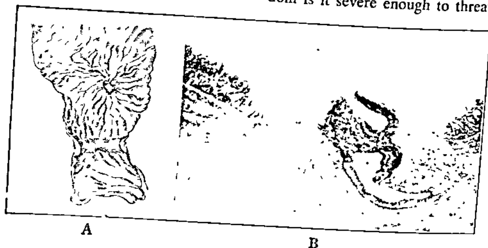


Fig. 15. Gastric ulcer leading to a fatal hemorrhage. A, the gross appearance of the specimen of stomach opened along the greater curvature. Note the "pipe-stem" artery projecting into the base of the small ulcer; B, photomicrograph showing cross-section of the artery which was responsible for the hemorrhage. Operation in this patient, a 26-year-old male, would have been the only way of controlling the bleeding from such a vessel.

passed the pylorus. Should vomiting become profuse, usual signs of water and electrolyte disturbance will occur unless losses are adequately replaced.

Treatment will depend to a considerable extent upon the degree of obstruction and how much of it is due to pylorospasm, how much to edema, and how much to actual stricture formation. Occasionally, gastric atony due to potassium deficiency simulates or is associated with gastric retention. The answer to these questions usually follows a period of careful observation and simple therapy which includes small, frequent feedings, alkali and antispasmodic drugs as indicated, and daily gastric lavage. The program is used merely as a therapeutic test. Progressive decreases in the amount of 24-hour retention indicate a favorable response, which indicates that part of the obstruction was due to edema, to spasm, or to both. Even if surgical therapy is indicated on the basis of past history, such preliminary therapy serves a useful purpose by decreasing operative difficulty through relief of edema of the gastric wall and of inflammation at the pylorus and duodenum. Should the patient be able to take an adequate diet after such therapy, the correction of some of the nutritional deficits will be almost automatic. In other cases, adequate preparation requires the parenteral replacement of water and electrolyte deficits as determined by careful history and examination of the patient. Occasionally, gastric atony due to potassium deficiency simulates or is associated with pyloric obstruction and requires the addition of potassium chloride to the parenteral fluids. In any case, with adequate preparation under these conditions, operation may be carried out with practically no risk and with a minimum of technical difficulties.

Gastric Cancer. Not only is carcinoma of the stomach common, it is also frequently "silent," producing relatively few symptoms in the early stages, during which surgical excision offers a chance of cure. Cancer, masquerading as an ulcer, as discussed already, is an exception and therefore offers a much more favorable prognosis. Of some theoretical interest are recent observations showing that certain blood groups have an influence in increasing the susceptibility to gastric cancer (46). In a large percentage of patients with gastric cancer, the disease has progressed beyond the stage of excision at the time operation is performed. This is due, of course, to the difficulty in early diagnosis, based in turn upon the fact that the symptomatology varies widely. Moreover, the more rapid the growth, the earlier the symptoms and the less favorable the prognosis, as discussed below. Cancer may occur in any portion of the stomach and, except for the fact that a peptic ulcer may be associated, may give no warning. The tumor may take the form of a surface growth which ulcerates and bleeds, or a more fungating type (Fig. 16). Others develop scirrhous characteristics. Unfortunately, the tumor often penetrates the stomach wall and metastasizes to adjacent lymph nodes and even to the liver before symptoms occur.

Cancer of the stomach should always be suspected in any individual, middle-aged or older, who develops digestive symptoms or anemia without apparent cause or precedent. These may be ever so slight, perhaps only an epigastric discomfort or anorexia; but if they persist, the patient should consult his physician, and, if the symptoms are not readily explainable, radiographic studies after a barium meal should be performed (Fig. 17). This examination will be of value only when carried out by an expert, and really constitutes our chief objective method of early diagnosis. Routine radiologic examinations of large numbers of patients have been carried out (similar to mass chest x-rays) in an attempt to detect early lesions. Unfortunately, the findings did not justify the tremendous expense and effort involved. Gastroscopic examination may be useful in some of the more doubtful cases. Less important is the examination of gastric contents which, in general, show abnormal findings only late in the disease. Anacidity, formerly considered of diagnostic value, is not always found in patients with gastric carcinoma. Moreover, normal individuals may have no acid in their gastric contents at the time of a single examination. Gastric analysis is, however, a useful screening test for cancer detection centers. Vomiting of food taken several hours previously is generally indicative of obstruction regardless of the cause; how-

ago as 1906, recommended the liberal feeding of bleeding peptic ulcer patients. Meulengracht popularized this form of therapy in 1935, following Andresen; Levy (43) extended it by adding protein hydrolysate to a mixture of milk and cream. The hydrolysate, he showed, maintains gastric anacidity much more effectively than other means, whereas the cream slowed gastric motility and seems to have a definite influence on increasing the coagulation of the blood (44).

To eliminate permanently the threat to life from a dangerously bleeding ulcer, it is considered best by most surgeons to perform gastrectomy with ligation of the bleeding point or excision of the bleeding point. The mortality of this procedure is low when the principles mentioned above have been observed. While it is true that operation is best performed during a quiescent period after an acute episode has subsided, since the mortality then can be as low as 2 per cent, operation is also reported to be relatively safe if performed early during the acute phase of bleeding, mortality rates being reported as low as 10 per cent. The factor to emphasize, however, is that operation becomes highly dangerous if carried out as a last resort, after several days of recurrent or continuous bleeding, particularly if during this period the patient has suffered continuing hypotension and/or anemia because of inadequate blood replacement. In such cases a mortality of 50 per cent has been reported by Welch (45), an experience in accord with that of the authors.

Several technical features of the operation may be mentioned. In some cases it may be difficult to find the bleeding site, but the search is aided if the operation is performed during an episode of active bleeding. Apparently in over half the cases a frank ulcer or superficial peptic erosion is the source. If no source of bleeding is found on exposure of the gastric and duodenal mucosa, a gastric resection is nevertheless usually advisable to remove difficultly recognizable tiny erosions and to control gastric acidity, either or both of which may have provoked the hemorrhage.

In a statistically controlled series of 110 cases of massive gastroduodenal hemorrhage with a circulating red cell mass below 18 grams per kilogram (normal is 30 grams per kilogram) or with a red cell count below 2.5 million per cu. mm., types 1, 2, and 3 of management, as outlined above, were found to give survival rates not statistically different from one another, although all three, after the study had been instituted, provided striking improvement over that observed prior to concentration on this problem. The extremely conservative management was accompanied by somewhat lower mortality than the operative methods, and immediate operation was slightly more effective than operation in selected cases only; a larger series is being assembled to achieve numbers of true statistical significance (Enquist).

Massive gastroduodenal hemorrhage, in summary, may be treated in any of several fashions, but, regardless of the fashion chosen, the patient must be kept under constant accurate scrutiny day and night, a factor of greater importance by far than the particular pattern of therapy chosen.

Obstruction. The history of a patient with duodenal ulcer will often reveal the development of pyloric obstruction. As long as no obstruction exists, the patient is usually relieved of symptoms after a meal or with alkali. However, as obstruction develops, vomiting becomes more prominent and less and less relief is obtained from eating or taking alkali; indeed eating usually aggravates distress after the obstruction becomes significant. The site of the obstruction is usually at the pylorus, thus may follow both gastric or duodenal ulcers located at this point. Indeed, such ulcers are often spoken of collectively as pyloric ulcers. Gastric ulcer may rarely lead to an obstruction higher up, producing what is known as an hour-glass contracture.

Pyloric obstruction is always suspected when the patient recognizes in the vomitus food eaten 24 hours or more before. The amount remaining in the stomach at intervals after a barium meal yields accurate information as to the degree of obstruction. In complete occlusion no barium will be found to leave the stomach, even after 24 hours. A simpler bedside method is first to empty the stomach by tube, then measure each 24-hour intake, empty the stomach again, and calculate by difference the amount which has



Fig. 17. Carcinoma of the stomach. The entire distal third of the stomach is deformed because of the tumor. Considerable obstruction is present as indicated by the film which was taken six hours after ingestion of the barium. At operation, the tumor was resectible, but diffuse edema of the tissues thereabouts suggested it was not curable.

nosis. Thus in the long survivals, symptoms had been present an average of 16.6 months, and the involved nodes in the specimens removed were located within 3 cm. of the tumor. By contrast, in the short survivals, the symptoms had started only 5.8 months before, and 83 per cent had involved nodes beyond 3 cm. from the tumor. Other differences were also described, but the distance between the line of resection and the tumor was not significant.

Other Gastroduodenal Lesions. *Foreign bodies in the stomach* occasionally require removal by operation, though on most occasions the foreign body is usually passed spontaneously. Even open safety pins are disposed of in this way without perforating the intestinal wall. The progress of a radiopaque foreign body may be determined by periodic x-ray examinations; however, if the object is sharp and becomes lodged for several days at some point, operation for removal is sometimes indicated, lest perforation occur (Fig. 18). Professional debris-swallowers are sometimes operated upon for the removal of glass, nails, chains, and other objects when they produce gastrointestinal symptoms. Food balls represent another type of foreign body most often developing around tough vegetable fibers, such as those in persimmons. These are called *bezoars*—if of vegetable origin, phytobezoars, and if of animal origin, usually hair, trichobezoars. Bezoars are generally discernible during radiologic examination after the barium meal, produce a variety of symptoms, including those of ul-



A



B

Fig. 16 Carcinoma of the stomach. A, a fungating lesion is present in the cardia of the stomach. B, this photomicrograph from another patient has an appearance typical of carcinoma of the stomach.

ever the presence of "coffee-ground" material in the vomitus is evidence of extensive ulceration and bleeding which is usually associated with gastric retention. Abdominal palpation may occasionally reveal the tumor, but only when it has reached a considerable size. Anemia and loss of weight are usually late manifestations. Often gastric carcinoma is detected first by noting occult blood in the stools.

Treatment of carcinoma of the stomach, to be curative, means radical gastric resection well beyond the pylorus into the duodenum and proximally, including excision of the greater omentum, often the spleen, and the associated lymph nodes, followed by some type of gastrointestinal anastomosis. Preoperative nutritional preparation and continuous gastric lavage to relieve edema due to obstruction are obviously necessary. The presence of metastases to the liver precludes chance of cure, unless it is single and can be excised widely. In the face of hopeless spread, palliation of obstructive symptoms may be achieved through gastrojejunostomy and thus life is prolonged for months—rarely for years—although resection even in the presence of metastases is frequently preferable because of the better symptomatic relief which follows the successful elimination of the infected bleeding tumor. Radiotherapy has been disappointing.

Linitis plastica is a special type of gastric carcinoma producing a diffuse scarring of the entire stomach, which assumes the appearance of a tough woodlike pouch, hence the name. Although total gastrectomy must be performed in order to eliminate all of the diseased tissue and permit a successful anastomosis, the end results are uniformly poor.

The long-term results of resection in gastric cancer have been disappointing and have not been appreciably improved by more radical operation, including total gastrectomy (47). While wide resection is essential, a careful study (48) of two groups of 34 cases, each with similar gross lesions, one surviving over five years and the other less than one year, show that it is the rate of growth of the tumor which is decisive in the prog-



Fig. 17. Carcinoma of the stomach. The entire distal third of the stomach is deformed because of the tumor. Considerable obstruction is present as indicated by the film which was taken six hours after ingestion of the barium. At operation, the tumor was resectible, but diffuse edema of the tissues thereabouts suggested it was not curable.

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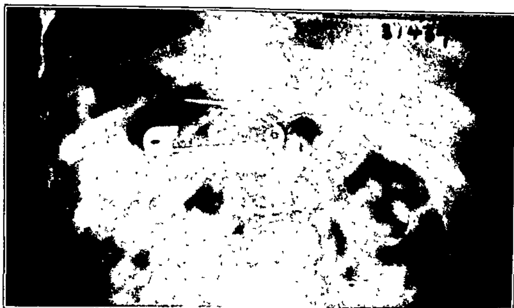


Fig. 18. Foreign body (safety pin) in the stomach. This roentgenogram was taken six days after the ingestion of the pin which first lodged in the esophagus (see Fig. 9). The pin remained at the same point during the six days, although the child, aged two years, suffered no symptoms. Laparotomy was performed and the pin removed through a gastrostomy opening; recovery was uneventful.

cer, and are usually so disabling as to demand operative removal of the foreign body by gastrotomy.

Polyps of the stomach occur and frequently are multiple. Diagnosis is made by x-ray or gastroscope in most cases. Excision by operation should probably be carried out even if the symptoms are not severe because of the danger of malignant degeneration. Occasionally, a polyp will be carried through the pylorus and produce a characteristic filling defect and symptoms simulating duodenal ulcer. The multiple adenomatous polyps seen in patients with pernicious anemia are so often a precursor of cancer as to justify excision, which may require total gastrectomy. *Leiomyoma, lipoma, carcinoid* (49), and other tumors including *aberrant pancreas*, though rare, may occur in the stomach and duodenum as they do elsewhere. The surgeon must be prepared to encounter any of them, often when least expected, since preoperative diagnosis is seldom made. *Lymphosarcoma*, when it occurs, is usually less invasive than carcinoma of the stomach, yielding better results following gastrectomy than carcinoma. Carcinoid occurs anywhere in the gastrointestinal tract and is discussed in detail elsewhere.

Syphilis of the stomach produces a thickening of the wall and a variety of mucosal ulcerations with a clinical picture and radiologic findings similar to those of cancer or peptic ulcer. The differentiation is difficult even at the time of operation, particularly since a patient with definite ulcer or carcinoma of the stomach may also have a positive Wassermann (see p. 116). Operation is nevertheless usually indicated since gastric syphilis produces symptoms due to scarring even after adequate antisyphilitic therapy.

Gastritis, as a pathologic and clinical entity, rests upon definite observations of the gastric mucosa with the flexible gastroscope. Various types have been observed and are supposed to be associated with definite clinical manifestations. Massive hemorrhages from gastritic stomachs have been frequently observed (Enquist). Otherwise, gastritis is largely of medical interest. Gastritis in the past was said to be significant in peptic ulcer, and many European observers maintain that gastritis precedes and is an etiological factor in ulcer. It is likely, however, that the gastritis is secondary to the ulceration. Phlegmonous gastritis, a rare disease, is due to extensive and severe infection of the stomach with systemic manifestations and a rapid fatal course. Treatment is palliative.

Acute dilatation of the stomach has been

discussed elsewhere. It occurs practically always as a postoperative or post-traumatic complication. The entire stomach gradually becomes more and more dilated with liquid and gas and produces more or less obvious upper abdominal distention and serious embarrassment (by pressure) to the heart and lungs. The patient is usually free from pain but vomits continuously, though in small amounts. Hiccup is often present and persistent. Diagnosis is generally easy if the condition is suspected; treatment is simple and effective. The passage of a stomach tube will yield one or more liters of stomach contents, and produces an immediate and marked improvement in the patient's local and general condition. It is usually necessary to leave the tube in place for a day or two or until external drainage from the stomach becomes insignificant. Indeed, the use of continuous gastric suction for 24 hours or more after operations will prevent the development of acute dilatation of the stomach.

Diverticulum of the duodenum is probably a congenital defect and is not infrequently noted by roentgenologists during an x-ray examination following a barium meal. The clinical significance is not great because it rarely produces symptoms and/or leads to serious disease. *Duodenitis* is a poorly understood lesion which is sometimes diagnosed only by the radiologist. *Annular pancreas* produces duodenal atresia and obstruction which often requires surgical relief, usually by gastroenterostomy.

Duodenal fistula is a rare, but distressing, postoperative complication following surgical procedures about the duodenum, stomach, and pancreas. The destructive action of the discharge from the opening on the tissues is due to the presence of active trypsin, which also produces the same changes in any high intestinal fistula. Treatment consists of drainage to the exterior and suction at the skin margin with some type of sump-pump to minimize digestion of the skin, which should be protected with a stiff ointment or powdered aluminum.

SMALL INTESTINE

Considering the great length of the small intestine (average 6.5 with a range of 3 to 8.5 meters), it is the site of relatively few surgical diseases. Polyps, adhesive bands, congenital anomalies(Fig. 19), intussusception, and postoperative adhesions, which cause intestinal obstruction, are described in Chapter 33. Cancer of the small intestine is rare. Acute infection, usually called gastroenteritis, may result from the ingestion of contaminated food and is of interest surgically only because it may be confused with acute appendicitis and lead to an ill-advised operation.

Regional Ileitis. Apparently first described by Combe and Saunders (49) in 1813, and named and brought to the attention of the medical profession by Crohn, Ginzburg, and Oppenheimer in 1932 (50), this rather remarkable granulomatous lesion, usually of the terminal ileum, is of unknown etiology. Anatomically, it consists of a subacute or chronic inflammation which leads to ulceration of the mucosa, edema, and connective tissue proliferation of the remaining portion of the wall. The diagnosis is often first made at operation, performed usually for suspected acute appendicitis. The involved ileum is found to be thicker and more boggy than normal; edema and hyperemic or cyanotic areas are noted in the serosa with visable beaded lymphatics draining into the mesentery therefrom. The mesentery is thickened and contains enlarged lymph nodes. Although usually located in the terminal ileum, there may be similar and independent ("skip") areas in other portions of the small intestine, and even in some cases in the large intestine.

The disease occurs at all ages, but usually starts in early adult life and runs an essentially chronic or intermittent course, producing symptoms for many months or longer, and then clinically subsiding, usually only to recur after an interval of apparent good health. The clinical manifestations vary considerably, but in the severe cases consist of fever, diarrhea, continuous loss of weight, and progressive anemia, thus resembling ulcerative colitis. Stenosis of the bowel may produce a typical picture of partial or complete intestinal obstruction, particularly in the later stages of the disease. Perforation of the ulceration, depending upon the rapidity with which it occurs, may rarely lead to general peritonitis, more commonly to a localized abscess, or to a persistent fecal fis-

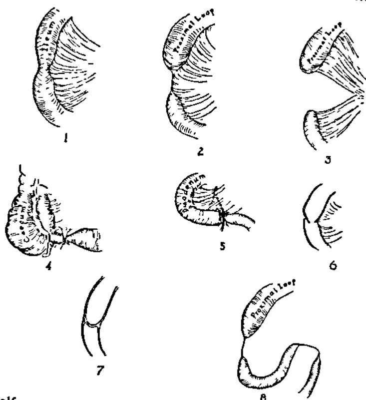


Fig. 19. Congenital malformations occurring in the small intestines. 1, stenosis with partial obstruction; 2, occlusion with blind loop; 3, blind loop with a gap in the mesentery; 4, obstruction by a fibrous band (found usually in the third part of the duodenum or the terminal ileum); 5, obstruction at the ligament of Treitz; occasionally an anomalous superior mesenteric artery is the chief factor in producing the obstruction at this particular site; 6, cross-section of intestine showing perforated diaphragm; this occurs usually in the duodenum or the terminal ileum; 7, cross-section of imperforate diaphragm, and 8, multiple occlusion of the ileum or jejunum; this constitutes about 15 per cent of the atresias of the intestine. Clinically, the dilatation of the proximal loop with collapse of the distal loop, is usually even more pronounced than shown in the illustrations. (From W. H. Cole. Arch. Surg.)

tula, either to the outside, to the vagina, urinary bladder, or the colon. Diagnosis during the chronic stage may often be made radiologically because of the characteristic findings at the site of the diseased bowel after the ingestion of a barium meal. Thickening and contraction of the gut wall typically lead to a stenotic area described on barium roentgen examination as the "string sign." However, carcinoma, tuberculosis, and actinomycosis of the cecum may produce similar manifestations and therefore must be considered in the differential diagnosis.

Treatment depends on the stage of the disease, the severity, and the presence of complications. Nonoperative therapy varies and occasionally leads to improvement of symptoms and even objective disappearance of the local and radiologic signs. Opinion is divided as to the place of operative intervention in regional ileitis. Some clinics believe medical management is indicated in cases with localized disease of short duration without complications and in cases with uncomplicated but widespread disease which might necessitate resection of too much bowel. Early surgical intervention is felt by some to decrease the chance of extension and the rate of severe complications (Dennis and Lear, 51). When medical management is employed, it may include adequate physical rest, proper nutrition, reduction of intestinal activity, correction of chemical imbalance by parenteral administration of blood, protein, and electrolytes, cortisone, psychotherapy, and antibiotics to control secondary infection. There is no evidence to indicate specific usefulness of any antibiotic for the primary disease.

After the abdomen has been opened and the nature of the disease established, closure of the abdomen without resection should be

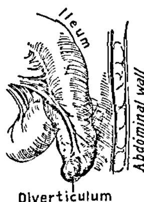


Fig. 20.

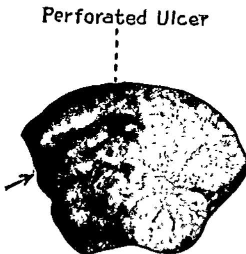


Fig. 21.

Fig. 20. The usual form of Meckel's diverticulum. Drawing of an intact specimen. Note that the proximal portion of the original vitelline duct persists, but having become closed at its end and detached from the umbilical region, it appears as a pouch hanging free from the convex border of the ileum. The omphalomesenteric vessels run up to its tip. (Redrawn from Kelly. The Vermiform Appendix, J. B. Lippincott.)

Fig. 21. Meckel's diverticulum showing a perforated peptic ulcer. Photograph showing the inside of the specimen which has been opened and laid flat. The patient was a six-year-old girl and was operated on for manifestations thought to be a general peritonitis of appendiceal origin. However, at operation the appendix was normal but there was a perforation in a Meckel's diverticulum, which was resected, the child making an uneventful recovery. The arrow points to the line of division between the ileal (above) and gastric mucosa (below), each verified by microscopic section. Note that the perforated ulcer is at the juncture of the two types of tissue. Another tiny ulcer can be seen in the middle of the aberrant gastric mucosa. (St. Louis City Hospital.)

restricted to those cases so hopelessly involved that surgical resection would be fatal. Simple short-circuiting of the diseased area once enjoyed a vogue, but has been abandoned because of the late poor results. The choice otherwise lies between exclusion of the involved segment and resection with end-to-end anastomosis. By exclusion is meant division of the gut proximal to the involved segment, closure of the end then in continuity with the involved segment, and end-to-side anastomosis of the cut end of the proximal bowel to healthy gut below the disease. Although the recurrence rate with resection is reported by some to be lower than with exclusion (Colp, 52 and Garlock, 53), the differences are not statistically significant. One series of 35 cases subjected to resection and followed up to 10 years shows a recurrence rate just under 10 per cent (Lear and Dennis, 51). The trend appears to be toward primary resection of involved areas (Crohn, 54). Truly curative therapy will be possible only when the cause of the disease has been found.

Meckel's Diverticulum. Originally described by the German anatomist, John Frederick Meckel, over a century ago, this congenital anomaly is an outpouching of the ileum about one to three feet from the ileocecal valve (Fig. 20) and in reality is a remnant of the obliterated vitelline duct of embryonic life (see p. 782). It is found in 2 per cent of individuals, and usually produces no symptoms. Associated lesions, however, may produce manifestations similar to acute appendicitis, or cause acute intestinal obstruction, or both. The diverticulum sometimes contains aberrant gastric mucosa (Fig. 21), which commonly produces a true peptic ulcer in the adjacent ileum. Such an ulcer may bleed or perforate. A band attached to it may produce intestinal obstruction or the diverticulum proper may lead to intussusception. Any or all of these complications usually occur in early childhood. Occasionally, however, Meckel's diverticulum first produces trouble in the form of acute intestinal obstruction in the later decades of life. Per-

foration produces acute, severe, abdominal pain, nausea, and vomiting not unlike peritonitis due to other causes. The correct bedside diagnosis will only rarely be made, unless one remembers to get a radiograph and finds a pneumoperitoneum. However, the acute abdominal sign will demand exploration during which the true nature of the lesion will be revealed. The peptic ulcer in Meckel's diverticulum may bleed and produce *anemia slowly*; but commonly, the bleeding is profuse, and shock follows. The ulcer may produce chronic abdominal pain of variable severity located in the right lower quadrant or about the umbilicus; a diagnosis of recurrent appendicitis is often made. When symptoms are vague or bizarre, radiography sometimes, but not always, may reveal changes suggestive of the correct diagnosis. During operations for unexplained abdominal pain the surgeon should always look for a Meckel's diverticulum.

Treatment is urgent in perforation, obstruction, or massive hemorrhage; the presence of abdominal pain, particularly if accompanied by persistent bleeding, will also justify operations in the patient with chronic manifestations, Excision of the sac with reestablishment of intestinal continuity is performed. For further details the reader is referred to a recent review of 60 cases (55).

Intestinal Fistula. Abdominal incisions which fail to heal should always be suspected of being intestinal fistulas. The diagnosis is, of course, obvious if fecal material can be recognized escaping from the wound. A direct identification of the fecal nature of drainage from the fistula is provided by a positive test for urobilinogen (Baronofsky, 56). If necessary, a colored substance, e.g., carmine, can be given by mouth; it will appear in the wound if a fistula is present. The higher the fistula, the sooner the color will appear, and the more irritated the skin about the wound will become. Most intestinal fistulas have a natural tendency to heal spontaneously. When closure does not occur within a few weeks or months, a specific cause must be established, such as one or more of the following: 1. an obstruction present distal to the fistula; 2. continuity of intestinal mucosa with the skin; 3. presence of a granulomatous infection, such as tuberculosis, actinomycosis, or regional ileitis; and 4. colloid cancer of the cecum. Indeed, these lesions may lead to spontaneous fecal fistulas.

The best *therapy* is adequate preparation by complete gastrointestinal rest, including gastric or gastrointestinal decompression if indicated, during which nutrition is maintained and deficits corrected by intravenous infusions, followed by excision of all diseased intestine, including parts of the abdominal wall if necessary with primary intestinal anastomosis and closure without drainage. Two or more staged procedures, including "exclusion" of the fistulous area, are no longer indicated as they were decades ago.

Acute Mesenteric Lymphadenitis. This condition occurs chiefly in children and is of surgical interest only because it produces abdominal pain, tenderness, nausea, and vomiting, and therefore simulates acute appendicitis. There is usually more fever than with early appendicitis, and the abdominal findings are more apt to be diffuse. The disease may follow or accompany various types of epidemic infections or of acute upper respiratory infection or poorly delineated types of enteritis. If the patient is operated upon, the appendix will be found to be normal or only slightly injected; the mesenteric lymph nodes are enlarged, often to a size 2 to 3 cm. in diameter. Microscopic section of these nodes reveals only a *diffuse* hyperplasia. Treatment is symptomatic; the abdominal manifestations usually subside spontaneously in a few days.

Typhoid fever sometimes causes perforation of the Peyer's patches in the small bowel, which, of course, represents an acute surgical emergency (p. 125). *Chronic mesenteric lymphadenitis* is usually tuberculous and is described under tuberculous peritonitis (p. 808).

THE APPENDIX

Although this small cecal appendage is the site of a few neoplasms, the most important disease of the organ is acute appendicitis.

Acute Appendicitis. Acute appendicitis is not only common, it presents many diagnostic problems, and leads to serious complications. A monograph by Boyce (57) contains valuable and detailed information and his-

torical data on the appendix. Acute appendicitis, despite the dramatic reduction in mortality in the past two decades, is still a frequent and serious surgical disease and respects no age, although it is more prone to occur in the teens and twenties. In children, it is especially serious because of the more rapid, though often atypical course, and the tendency for early perforation. In the elderly, it is also a problem diagnostically, for here again it fails to provide the typical clinical picture seen in young adults. Before the days of chemotherapy it accounted for nearly 20,000 fatalities a year in the United States alone. This high toll of life has been reduced to less than 5,000 (in 1950), despite the increased population, and can be lowered even more provided a prompt diagnosis can be made and appendectomy can be carried out in every case. Undoubtedly, the widespread use of cathartics, stimulated by ignorance and unethical advertising, is an important obstacle. Chemotherapy aimed at avoiding operation may also prevent further reduction in mortality.

The enigma of the *pathogenesis* of appendicitis has been approached from many angles. Van Zwalenberg (1904) first demonstrated that sustained intraluminal pressure in the cecal appendage of the dog leads to necrosis of the wall and ultimate perforation. Wangensteen and Bowers (58) noted that in clinical human appendicitis with gangrene or perforation there is invariably complete organic obstruction of the lumen. Laboratory studies have shown that, of the readily available animals, only the rabbit, the chimpanzee, and man have appendices which regularly secrete fluid at pressures high enough to lead to gangrene and perforation following ligation obstruction with preservation of the blood supply (Dennis, Buirge, and Wangensteen, 59). Although it has been speculated that blockage of the large blood vessels to the appendix is a factor, such blockage experimentally fails to produce the picture seen clinically. Ligation obstruction of the lumen regularly produces the clinical and pathologic findings of appendicitis in the chimpanzee, the rabbit, and man (Wangensteen and Dennis, 60; Dennis, Buirge, and Wangensteen). The precise stages in which pathologic changes develop after obstruction have been delineated in the rabbit and are parallel to those seen clinically (Dennis, Buirge, Varco and Wangensteen, 61).

The factors which lead to luminal obstruction have also been studied. The roentgen-cinematographic studies of Wildegans (62) showed the normal appendix of man to fill from and empty into the cecum every few hours. The facts that the fecaliths frequently found in association with appendicitis usually contain identifiable vegetable seeds at the centers and that a few well-studied cases of appendicitis, including those of D. P. D. Wilkie (63), who first postulated the obstructive origin of appendicitis, have been observed in which ingested bird shot have been found in the lumina—both sustain the thesis that irritation of luminal content is a factor. Swelling of the abundant lymphoid tissue within the circular musculature appears occasionally capable of production of sufficient obstruction; Bowers found in army personnel six times the incidence of appendicitis in the period after immunization injections against typhoid fever than in a control group.

The musculature of the appendiceal wall is an important factor also. A generous share of cases less severe than gangrene has been found to exhibit an elevation of measured resistance to flow through the lumen, which is obliterated by permitting the muscle to relax by the lapse of an hour after removal. The usual partial relief of symptoms seen in clinical appendicitis and the occasional abortion of an attack by administration of 0.5 ml. of adrenalin (1:1,000), which acts by marked relaxation of the circulatory musculature, also testify to the importance of this tissue (Dennis, 64).

Summarization of observations indicates that, initially, irritation of the appendiceal wall by material entering from the cecum leads to a localized area of inflammatory reaction and secondary mucosal edema and muscular contracture. Pressure rises distally from continued secretion of fluid at 3 to 4 ml. per day in a space normally less than 0.1 ml. Secretion continues until the muscular component of the obstruction is overcome or relaxed by the degree of inflammatory reaction, and empyting into the cecum occurs. Subsequent bouts occur, but residual fibrosis from preceding attacks renders spontaneous

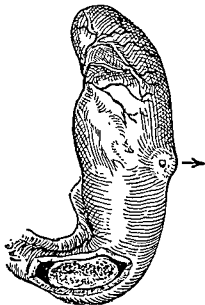


Fig. 22. Gross specimen of an acutely inflamed, perforated appendix, removed eighteen hours after the onset of acute abdominal pain. Note the fecalith impacted at the base of the rather short appendix, producing an acute obstruction to the lumen, and the tense swollen part distal to it in the middle of which is the site of perforation indicated by the arrow.

decompression progressively less likely until ultimately complete organic obstruction results in gangrene and perforation.

An attempt to evaluate this thesis, made by interview of 150 patients with gangrene or perforation of the appendix, shows that 83 per cent of them gave histories of previous bouts, and more than half of these of bouts of progressively increasing severity until gangrene or perforation occurred.

In the occasional case found to have complete organic obstruction without gangrene or perforation, the mucosa is fragmented and thin, and apparently the response to previous attacks has been mucosal destruction alone without full-thickness gangrene. In these cases, the mucosa recovers in one to three weeks, again to cause trouble.

In review of the clinical implications, pressure rise secondary to continued secretion in the face of luminal obstruction (e.g., fecalith, as shown in Fig. 22) appears conclusively to lead to ischemic necrosis of the mucosa and secondary invasion by whatever bacteria happen at the moment to be in the lumen. The experiment of ligation obstruction of the lumen in the rabbit shows well-developing changes of ischemic necrosis at three to four hours, at which time no febrile or leukocytic response has occurred and no pathologic infiltration into the appendiceal wall is yet fully developed. The initial pain, tenderness, nausea and vomiting, and even apparently localization to the right lower quadrant, can be induced in man under local anesthesia. It is possible, therefore, that the very alert physician may suspect and diagnose acute appendicitis by these historical and laboratory items and localized right lower quadrant tenderness in advance of fever and leukocytosis, and possibly even before development of pathologic changes which can be found by examination of the removed appendix.

Clinical Manifestations. Abdominal pain, nausea and vomiting, and tenderness in the right lower quadrant are the three chief abdominal manifestations which should lead the patient or doctor to suspect acute appendicitis. The *pain* is often characteristic, starting in the epigastrium or generalized at first, but soon shifting to the region of McBurney's point, which in adults is 2 inches from the anterior superior spine of the ilium on a line drawn from this process to the umbilicus. The pain is only moderately severe but disabling, often inducing the patient to seek bed rest. Great variations occur, depending on many factors, including the location of the appendix, which may be retrocecal, extend over the brim of the pelvis, or upward toward the umbilicus. In gangrenous appendicitis, pain may be slight or absent. On the other hand, if the appendix lies along the ureter or near the base of the urinary bladder, the pain will radiate into the testicle or thigh and it may produce pain on urination. Such variations, though exceptional, will influence the severity, nature, and location of the pain. *Vomiting* is an important symptom and characteristically is *preceded by pain* and nausea. It may occur but once or twice, or be completely absent, particularly in the early stage of the disease, though nausea is usually present. Provoked pain, usually called tenderness (see below), localized to the acutely inflamed organ, is undoubtedly the most valuable single sign of acute appendicitis because it is the most frequent and least variable.

Abdominal tenderness may be observed by the patient because of the pressure exerted by his clothes. He frequently prefers to lie with his thighs and knees flexed because of relief of pain afforded by this position. Abdominal tenderness is most evident when the appendix is free in the peritoneal cavity. Careful, thorough examination will, in most cases, suggest the location of the inflamed appendix by finding the site of maximum tenderness. Palpation will also elicit *muscle spasm*, the degree of which varies roughly with the severity of the infection and becomes generalized only when the appendix has perforated and general peritonitis has started. It must be remembered that, at times, acute appendicitis may actually progress to perforation without muscle spasm, particularly if the appendix is surrounded by adhesions or other organs or is retrocecal. When the appendix is retrocecal, tenderness may be slight or elicited only on deep palpation, but tenderness posteriorly may be significant. At times, localized right lower quadrant tenderness will be elicited only with the patient in the prone position, the examiner's hands being placed underneath the abdomen. Rebound tenderness, i.e., on sudden release of palpation, should be noted when present, for it may be found in the absence of muscle spasm or ordinary tenderness. The pressure of palpation in the left lower quadrant often produces pain in the right lower quadrant (*Rovsing sign*). On many occasions, *rectal examination* will reveal definite tenderness when the appendix lies along the posterior wall or over the edge of the pelvis. Rectal examination is essential in every suspected case of appendicitis, for in some, right tenderness may be the only objective physical finding (Harold Neuhof).

Leukocytosis usually appears shortly after the onset and is often progressive (12,000 to 18,000 per cu. mm.). Even when the count is normal, a differential will usually show an abnormally high percentage of polymorphonuclear forms. Although the pulse rate and temperature will usually rise sooner or later in the course of acute appendicitis, the physician *should not wait for fever* before he makes a diagnosis of acute appendicitis. Constipation is usually present. Diarrhea is *not* a part of the usual clinical picture in acute appendicitis unless provoked by ill-advised catharsis. Diarrhea may accompany appendicitis when the appendix lies along the anterior rectal wall. In such a case, localized exquisite tenderness may be felt on careful rectal examination. Acute appendicitis may also occur during a siege of diarrhea as a complication of acute enteritis which, on rare instances, becomes an instigating factor in the production of acute appendiceal inflammation. The history of diarrhea *preceding* the pain of acute appendicitis is usually characteristic.

Acute appendicitis during pregnancy deserves special mention because of the high mortality which follows perforation in a pregnant woman. Operation is therefore more urgently indicated. Local tenderness is important and is often a guide to the site of incision, since the appendix is normally displaced upward by the enlarging uterus.

Later manifestations are due to the complications already mentioned, i.e., local or general peritonitis (see Ch. 32, and below). The pain was formerly thought to diminish after perforation, but in a review of 150 patients with gangrenous or ruptured appendices only six had such a decrease in pain, a proportion smaller than seen in those without perforation. Vomiting, however, recurs and persists as more peritoneal surface becomes involved, and local tenderness spreads. *Fever* is a delayed manifestation of infection, being significant only at the time of or following perforation (except in children in whom it occurs earlier); it is therefore *not* necessary in the establishment of an early diagnosis. It is unfortunately true that many practitioners wait for fever before making a definite diagnosis of appendicitis and therefore get these patients to the hospital only after local or general peritonitis is present.

Differential Diagnosis. Since early appendectomy is the universal treatment, the only problem in acute appendicitis is early diagnosis. Unfortunately, many diseases simulate acute appendicitis. In a few, operation is contraindicated and if performed may lead to a fatal outcome. Thus, the surgeon is often confronted by a Scylla and Charybdis, a dilemma which, in some cases, may tax the most experienced and careful observer. The type of pain is important in establishing a di-

agnosis of acute appendicitis; elimination of this disease, diagnostically, is often made difficult by exaggeration or inaccuracy in the patient's description of pain. Vomiting is likewise important, especially because in appendicitis it rarely occurs *except when preceded by pain. Local tenderness usually associated with muscle spasm* is undoubtedly the most valuable manifestation, particularly when elicited by careful and expert abdominal palpation, the importance of which cannot be overemphasized. In the following discussion, three groups of conditions will be described, each capable of simulating acute appendicitis, but differing, sometimes decisively, in the eventual outcome should a mistake in diagnosis and therapy be made.

1. Of the various specific diseases which *simulate acute appendicitis,* one may, to some extent, dismiss those for which *operation is indicated.* These include perforated ulcer, intestinal obstruction, twisted ovarian cyst, perforation of a viscus, as well as many other similar surgical conditions. Since abdominal exploration is necessary in all of them, an erroneous diagnosis will not jeopardize the patient unless the actual lesion is not recognized at operation.

2. Most important are the diseases in which *operation is contraindicated* because of the threat to life posed by the operation. In this group are lobar pneumonia, acute nephritis, idiopathic (primary) peritonitis, coronary disease, and amebic dysentery.

In *lobar pneumonia* the pain may be referred to the abdomen when the diaphragmatic pleura is involved. However, the abdominal signs are absent or confined to the upper abdomen; the patient has a rapid respiratory rate; there is dilatation of the nasal alae and sometimes slight cyanosis. Chest examination in early pneumonia may reveal few signs, and roentgenograms may prove negative. With care and observation for several hours, differentiation should not be difficult.

In *acute nephritis* there may be vomiting and abdominal tenderness with rigidity of diffuse character. The presence of abnormal urinary findings (albumin, casts, blood) and evidence of renal insufficiency (high blood urea and nonprotein nitrogen) are characteristic.

Idiopathic peritonitis produces diffuse abdominal signs and is described on page 806. However, with the preoperative and postoperative use of chemotherapy the mistake of operation in this disease is of little danger as compared to the hazard in the days before chemotherapy.

Coronary thrombosis and occlusion not infrequently produce abdominal pain which, however, is located in the epigastrium and ordinarily is confused with perforated ulcer, biliary colic, and acute pancreatitis. The presence of dyspnea, orthopnea, and cyanosis indicates cardiac rather than abdominal disease.

Amebic dysentery produces acute, diffuse, cramplike pain with mucus, pus, and blood in the stool, and diarrhea. Amebas can usually be found in the stool. Atypical cases simulate appendicitis and, if erroneously operated upon, are associated with a high mortality.

3. In the final group *operation is not indicated* but is, at least, associated with little risk. These conditions comprise the following: fecal stasis (constipation), spastic colitis, acute enteritis, gastric crises (tabes dorsalis), rupture of a Graafian follicle, acute pyelitis, acute right-sided salpingitis, intestinal allergy, acute epididymitis, ureteral stone (renal colic), and abdominal wall pain. Thorough physical and laboratory examination is usually all that is needed to make the diagnosis. Thus it will exclude *pyelitis* (pus cells and bacteria in the urine) and *gastric crises* (absent knee kicks, Argyll-Robertson pupils, and so forth).

In *fecal stasis* the pain is slight, there are no signs of peritoneal inflammation; rectal examination may reveal sphincter spasm and fecal impaction. An effectual enema usually affords relief.

In *spastic colitis* there may be a history of mucus in the stool associated with constipation, perhaps with occasional attacks of diarrhea. A spastic cecum may be palpated.

In *acute enteritis* the history of eating spoiled food or of a dietary indiscretion may or may not be obtained; diarrhea is always present and the pain is diffuse and cramplike in character and does not tend to localize.

In *acute mesenteric lymphadenitis* the abdominal signs are marked but not localized.

There may be rigidity and severe tenderness almost as great as that found in perforated ulcers, but the signs are diffuse and are usually equal on the two sides. The disease is present only in children and is usually associated with a red, inflamed throat, fever, leukocytosis, prostration, and vomiting (see also p. 799).

In *rupture of a Graafian follicle* the pain, while severe, is of short duration with only transient local tenderness; its occurrence during ovulation is suggestive.

Patients with *salpingitis* due to the gonococcus usually give a history of vaginal discharge and urethritis (frequency and pain on urination). The facial appearance of these patients, even when the pulse is high and temperature is elevated, is characteristic, because it lacks the pained, anxious expression, and they do not appear so ill as do patients with acute appendicitis. The local signs are lower in the abdomen and pelvic examination usually reveals the nature of the lesion.

The pain accompanying *intestinal allergy* may be severe, but local signs in the right lower quadrant are usually not present; the differential blood count may show an eosinophilia.

Acute epididymitis may simulate the local signs of acute appendicitis when the inflammation extends up into the vas and seminal vesicle, and pain is referred up into the abdomen; examination of the testicle, however, is all that is necessary to detect the origin of the symptoms.

In *renal colic*, differentiation may be difficult or impossible although the pain is usually much more severe and colicky in nature and ordinarily radiates along the ureter and down one thigh or into the perineum. Blood may be found in the urine, and an x-ray may reveal a stone. When the appendix lies along the right ureter, however, it may, when inflamed, produce the same pain as a stone and even lead to hematuria. The local signs and leukocytosis serve to differentiate it from stone.

Abdominal wall pain is nearly always aggravated by movement of the spine and is often associated with obvious evidence of acute sacroiliac or lumbosacral sprain. Palpation of the abdominal muscles between the fingers often enables the examiner to localize the tenderness to the muscles. Abdominal wall pain is frequent and often a source of confusion unless it is kept in mind (Carnet, 65).

There are many other diseases which, on rare occasions, offer difficulty in differential diagnosis, such as Meckel's diverticulitis, tuberculosis of the cecum, regional ileitis, carcinoma of the colon, cholecystitis, and acute interstitial pancreatitis, all of which are discussed elsewhere.

As in other diseases certainty is often impossible in the differential diagnosis of acute appendicitis. Therefore, the surgeon must recognize and face the possibility and consequences of a mistaken diagnosis. Two kinds of mistakes may be made: (1) the surgeon may operate and find no surgical lesion, or (2) he may fail to operate and find that the patient has developed a peritonitis from perforation of an acutely inflamed appendix which he has failed to diagnose. In weighing the relative seriousness of these two mistakes, he thinks of the following considerations. First, the mistake of operating when no surgical lesion is present is harmful only if the patient is actually suffering from one of the diseases mentioned in the second group just discussed, such as pneumonia, coronary disease, nephritis, and amebic dysentery. If they can be excluded, the mistake is less serious because recovery practically always occurs. Careful study has shown that in the best hands such a mistake is made in about 10 to 20 per cent of appendectomies performed for suspected acute appendicitis. On the other hand, to fail to operate on a patient with acute appendicitis is clearly a serious mistake for reasons already mentioned. It is largely of the danger of peritonitis that most surgeons, when confronted by a difficult problem in differential diagnosis, will obviously prefer to make the lesser of the two mistakes discussed above.

TREATMENT. As stated by William Osler in his textbook of medicine, first published in 1902: "There is no medical treatment for acute appendicitis." Unfortunately, errors are still common and are probably responsible for the still excessive and unnecessary mortality in this disease. Catharsis pyramids the risk, not by alteration of the disease process in the appendix but by inducing sufficient

intestinal activity to prevent "walling-off" of the inflammatory process by adhesions of bowel and omentum (Dennis, Buirge, Varco, and Wangensteen, 61). In many cases, such dangerous treatment is self-inflicted; sad to relate, physicians are sometimes guilty. Often a cathartic is prescribed over the telephone. A drug clerk frequently advises it in order to sell some medicine. It is fortunate, however, that nature remedies the error in many cases by inducing immediate vomiting with consequent ejection of the cathartic. Nevertheless, the mortality records of acute ruptured appendicitis are filled with instances of unnecessary sacrifices to the great American practice of purgation. Many observers have recorded such evidence; Keyes (66), for example, found that the mortality of acute appendicitis in patients receiving cathartics was eight times greater than in those not receiving such medication. The rule should be emphasized that *laxative drugs are contraindicated in the presence of abdominal pain.* If a bowel movement is desired, an enema or a glycerin suppository will achieve a result with little or no danger, even if acute appendicitis is present.

A second dangerous form of treatment is the *indiscriminate use of morphia* to allay abdominal pain. This is unfortunately practiced by many careless physicians who make no diagnosis and who do not perform an adequate abdominal examination. The changes leading to perforation and peritonitis go on while the patient is blissfully sleeping with the aid of the magic hypodermic. But on awakening he may no longer have acute appendicitis—he may have a severe general peritonitis. Such a rapid progress is especially apt to occur in children.

A third and recently increasing yet potentially harmful trend is for physicians to use *chemotherapy for undiagnosed abdominal pain.* This may be disastrous if the patient is suffering from acute appendicitis, for there is no way of being sure that perforation is completely avoided thereby. Indeed, the antibiotics often mask symptoms of inflammation and increase the difficulty of diagnosis until the peritonitis is too far advanced to help by appendectomy.

The *safest treatment* for acute appendicitis is, therefore, an immediate and properly performed appendectomy. The mortality following operation before perforation is practically nil. Spontaneous subsidence, as already mentioned, frequently occurs, but can seldom be predicted unless the patient is seen at a time when he is obviously recovering from the acute attack and is clearly improving as shown by the history and examination. Appendectomy in such cases may still be indicated, but only as a prophylactic measure, especially if there have been previous attacks. The diagnosis in such a case is *recurrent appendicitis* and the operation is called an interval appendectomy.

COMPLICATIONS OF ACUTE APPENDICITIS. The complications of acute appendicitis vary with the degree and type of peritoneal infection which follows perforation or gangrene. Although a general discussion of peritonitis is found in Chapter 32, the special features of appendiceal peritonitis are described as follows.

General peritonitis, when well developed, offers no difficulty in diagnosis and usually follows neglect or mistreatment. On the other hand, the early manifestations after perforation, beginning with the first invasion of the peritoneum, are slight and, indeed, may be accompanied by a transient diminution in pain and local signs. As the infection gains a foothold, however, it may localize and form an abscess, which is discussed separately. If the infection spreads, the abdominal and systemic manifestations gradually or rapidly increase. In the full-blown case the patient becomes extremely ill or prostrated, "toxic," dehydrated, and distended. The various gradations in the degree of invasion are often referred to as local, spreading, or general peritonitis, a classification which is, however, often difficult at the bedside and even at the time of operation. After removal of the perforated or gangrenous appendix, the infection subsides, although residual abscesses may form later (see below).

In the past, the mortality has been high in severe and well-developed general peritonitis of appendiceal origin. Because of this, surgical opinion and practice were divided. One group claimed that the mortality could be lowered by removing the cause of the peritonitis by prompt operation despite the risk of the procedure in a seriously ill patient.

The other group maintained that more patients would survive by not operating and relying upon spontaneous localization. This difference has tended to disappear since the advent of chemotherapy. In any case, all surgeons would agree on the use of gastric decompression and chemotherapy and the replacement of deficits by parenteral infusions. Most surgeons, however, would operate promptly, using such measures merely as preoperative preparation. The present authors approve of and practice this policy in contrast to the older one of adopting a nonoperative program based upon the belief or expectation that localization and eventual subsidence of the infection will occur.

Modern combined chemotherapy has actually strengthened the advantages of early operation because, by reducing the operative risk even in those with severe septicemia, it has supported the principle of removing perforated lesions as soon as possible after the diagnosis is made. This principle is based on the well-known ability of the peritoneal cavity to resist rather severe bacterial invasion provided the source of the contamination is removed. If the source is not removed, the repeated contamination may be more than the peritoneum can withstand. While it is true that localization around a perforated or gangrenous appendix frequently occurs, it is difficult to be sure that it is actually taking place. The danger of spreading the infection by operation has been greatly exaggerated and, in any case, much reduced or eliminated by effective combined chemotherapy. It should be emphasized, however, that chemotherapy should be started before the operation so that the tissues will be well saturated with the agents when the anesthesia is given. At the St. Louis Children's Hospital only one child has died following prompt operation for appendiceal peritonitis since the use of combined chemotherapy. In that case, death one week after appendectomy was due to a Friedlander's bacillus pneumonia; at autopsy the peritoneum was clear. Unfortunately, newer antibiotics effective against this organism, now available, were unknown at that time.

Drainage of the area of appendiceal infection or of an actual abscess without appendectomy is undesirable but occasionally is done because of an extreme degree of inflammation. In practice, too, it is the rare case, indeed, in which the cause of the infection cannot be found, the damaged or necrotic appendix removed, and the stump closed. Drainage will thus seldom be necessary except when an abscess wall is present or when the cecal wall is badly inflamed and might perforate.

Appendiceal abscess is suspected when a definite mass is found on admission with a history suggesting an attack of acute appendicitis. Such a history may date back for weeks or a month or more, the mass having been present for this length of time. Under such circumstances, a differential diagnosis between an abscess and a neoplasm may be difficult but may be aided by radiologic study with a barium meal. In most cases, however, the history is shorter and the local findings of acute inflammation indicate that the mass is actually of appendiceal origin.

Treatment should be based upon the fundamental principles of prompt operation, as mentioned above, although the urgency may not be as acute as that existing in the treatment of abscesses in general (67), because the mass may be produced by indurated omentum surrounding an unperforated appendix. Even though nonoperative therapy for many weeks may lead to disappearance of the abscess, permitting an interval appendectomy later, the delay involved usually means a much longer period of convalescence than would be the case with prompt operation.

Residual abscesses, since the advent of chemotherapy, are much less common, but are suspected in patients in whom fever fails to subside in a few days, or recurs after it has returned to normal, usually within the first week or ten days. The various sites of such residual abscesses are illustrated in Chapter 32, Figure 5. In most cases of appendiceal infection, however, the most frequent location is in the pelvis. Clinical detection is relatively easy if the surgeon will remember to do frequent rectal examinations. A bulging cul-de-sac into the anterior wall of the rectum, accompanied by localized tenderness and induration, is diagnostic. Such abscesses usually rupture spontaneously into the rectum with complete relief. If this does not occur promptly and the abscess by palpa-

intestinal activity to prevent walling-off of the inflammatory process by adhesions of bowel and omentum (Dennis, Buirge, Varco, and Wangensteen, 61). In many cases, such dangerous treatment is self-inflicted; sad to relate, physicians are sometimes guilty. Often a cathartic is prescribed over the telephone. A drug clerk frequently advises it in order to sell some medicine. It is fortunate, however, that nature remedies the error in many cases by inducing immediate vomiting with consequent ejection of the cathartic. Nevertheless, the mortality records of acute *ruptured appendicitis* are filled with instances of unnecessary sacrifices to the great American practice of purgation. Many observers have recorded such evidence; Keyes (66), for example, found that the mortality of acute appendicitis in patients receiving cathartics was eight times greater than in those not receiving such medication. The rule should be emphasized that *laxative drugs are contraindicated in the presence of abdominal pain.* If a bowel movement is desired, an enema or a glycerin suppository will achieve a result with little or no danger, even if acute appendicitis is present.

A second dangerous form of treatment is the *indiscriminate use of morphia* to allay abdominal pain. This is unfortunately practiced by many careless physicians who make no diagnosis and who do not perform an adequate abdominal examination. The changes leading to perforation and peritonitis go on while the patient is blissfully sleeping with the aid of the magic hypodermic. But on awakening he may no longer have acute appendicitis—he may have a severe general peritonitis. Such a rapid progress is especially apt to occur in children.

A third and recently increasing yet potentially harmful trend is for physicians to use *chemotherapy for undiagnosed abdominal pain.* This may be disastrous if the patient is suffering from acute appendicitis, for there is no way of being sure that perforation is completely avoided thereby. Indeed, the antibiotics often mask symptoms of inflammation and increase the difficulty of diagnosis until the peritonitis is too far advanced to help by appendectomy.

The *safest treatment* for acute appendicitis is, therefore, an immediate and properly performed appendectomy. The mortality following operation before perforation is practically nil. Spontaneous subsidence, as already mentioned, frequently occurs, but can seldom be predicted unless the patient is seen at a time when he is obviously recovering from the acute attack and is clearly improving as shown by the history and examination. Appendectomy in such cases may still be indicated, but only as a prophylactic measure, especially if there have been previous attacks. The diagnosis in such a case is *recurrent appendicitis* and the operation is called an interval appendectomy.

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Fig. 24. Chronic appendicitis. Note the bands of adhesions and the kink in the appendix, produced by inflammatory scar. These fibrous bands are not to be confused with congenital bands which are due to anomalies in the development of the appendix and cecum. In many instances the past history is the only method of differentiation. In this case there was a history of several severe attacks due definitely to acute appendicitis which subsided.

velops. The relief of symptoms after appendectomy is common in these cases. It is the best proof of the above-mentioned pathogenesis.

"Chronic" Appendicitis. Aside from recurrent appendicitis and appendiceal colic, there remain a few patients in whom a diagnosis of chronic appendicitis may be justified. This designation in the past has been common, often based, however, on insufficient clinical evidence and after appendectomy on little or no pathologic change in the organ, and with no relief of symptoms, often, indeed, by an exaggeration thereof.

The *pathology* of "chronic" appendicitis is ill-defined except for the presence of fecaliths and peritoneal adhesions. Manometric determination of the pressure required to push fluid through the appendix and into the cecum commonly, in these cases, shows the resistance to flow to be higher than the upper limit of normal (30 cm.) and may be diagnostic in the absence of microscopically observable inflammatory reaction (Dennis, 1941). The presence of inflammatory scar, usually called adhesions (Fig. 24), as well as local *obliteration of the lumen* from previous infection, is often definite and is probably contributory to the obstruction responsible for symptoms. Lymphoid hyperplasia has also been described. In these cases, the surgeon may occasionally discover small tumors in the appendix, as described on page 760. Pinworms (Oxyuris vermicularis) are sometimes found in the appendiceal lumen and may have been responsible for symptoms. In rare instances, small foreign bodies are found.

Clinical Manifestations. The usual *clinical picture described as chronic appendicitis* consists merely of a discomfort of a persistent sort located in the right lower quadrant. The pain is chronic in character and may vary in degree with a variety of circumstances. The surgeon should, if possible, examine the patient during an exacerbation of the pain with the idea of eliciting local tenderness which may be of aid in localizing the source of the pain. Otherwise, in most instances abdominal examination will be negative. In some patients, the manifestations will be similar to those produced by duodenal ulcer, including epigastric distress *with tenderness, sour eructations*, and relief of pain by food. Since radiologic study reveals no evidence of duodenal ulcer, pylorospasm may perhaps be the factor responsible for the clinical symptoms. In many cases, these patients are young women and girls who suffer from chronic fecal stasis (constipation), or spastic colitis, or pelvic disease. In others, the pain may be a manifestation of lumbosacral sprain or psychogenic. These

tion is soft and fluctuant, it may be opened by an incision. When the location of a residual abscess cannot be determined accurately and the general condition of the patient is not improving, exploration may be justified and should be carried out preferably through an abdominal approach. Prompt timing in association with well-selected chemotherapy is important.

Wound infection may occur after operation for perforated appendicitis, particularly if the abdominal incision has been closed without drainage. Careful toilet of the contaminated wound by isolation of the wound edges with heavy gauze pads and irrigation with saline will minimize this complication. Diagnosis and treatment are the same as other postoperative wound infections, as discussed in Chapter 14. *Subdiaphragmatic abscess* sometimes occurs but is usually late; it should be suspected whenever the patient's temperature has returned to normal but recurs. The detection and diagnosis are discussed in detail on page 803. *Fecal fistula* is rare and suspected only when the drainage following operation for perforated appendicitis is necessary because of involvement of the cecal wall in the infection. Healing usually occurs eventually, particularly if there is no obstruction, as shown by the presence of normal bowel movements.

Sinus formation may be produced by any one of several factors including a foreign body, usually a fecalith, in the depths of the wound, or the presence of an unsuspected disease, such as actinomycosis, regional ileitis, colloid carcinoma of the cecum, or tuberculosis. The sinus must, of course, be differentiated from fecal fistula. *Pylephlebitis* is now practically nonexistent since the advent of chemotherapy. It is suspected when the patient develops a chill and high fever early in the disease (as discussed elsewhere). *Intestinal obstruction* is discussed in detail in Chapter 33. *Paralytic ileus* is really a normal phenomenon after operation for perforated appendicitis, in the presence of general peritonitis. After removal of the perforated appendix, however, the symptoms usually disappear.

APPENDICEAL COLIC. The onset of appendiceal colic is the same as that of acute appendicitis inasmuch as the pain is due to



Fig. 23. Gross specimen of an appendix, bisected, showing numerous fecaliths, which produced appendiceal colic. The patient, a 16-year-old girl had had many attacks of right lower quadrant pain, short in duration but severe and becoming so frequent as to produce serious disability. Complete relief followed appendectomy.

appendicular obstruction, usually caused by a fecalith which occludes the lumen (Fig. 23) with a resultant distention and hyperperistalsis. Although the pain is severe, it is transient and is rarely accompanied by vomiting and only occasionally by nausea. Attacks are frequently characterized by severe pain of a duration of a minute or two followed by a few minutes' relief, the pain alternating between the right and left lower quadrants; this diagnostic observation has been confirmed experimentally by deliberate placement of bird shot in the lumen of an appendix made available by appendicostomy (Dennis, 1941). Repeated attacks lasting from a few minutes to a few hours, leaving as rapidly as they come, may eventually, however, cause disability in themselves. Moreover, they always create a threat that at any time a total obstruction will follow and lead to inflammation and acute appendicitis. Fecaliths may be demonstrable in the appendix by radiography after a barium meal or an enema, but there is no proof that they have etiological significance. Appendectomy in appendiceal colic is curative, provided the diagnosis is correct, but is not urgent unless evidence of acute appendicular obstruction followed by inflammation de-

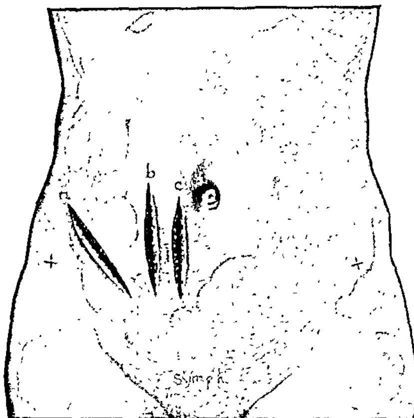


Fig. 25. Three types of incisions commonly used in operations for appendicitis. A, the McBurney, or gridiron (muscle splitting) incision. B, pararectus incision, the rectus muscle is split longitudinally instead of being retracted. C, paramedian incision, retracting the muscle laterally; this is used particularly when the diagnosis is uncertain, *since it affords better exposure than a McBurney incision.* (Schweich, after Brödel.)

of pelvic or upper abdominal structures through a McBurney incision, and it is difficult to locate an abnormally placed appendix in this way. The *perforated appendix should* be located and eliminated; this implies adequate exposure. Only rarely, if ever, will the exploration necessary to do so be too great to justify drainage alone. Careful exploration is also necessary to locate and remove fecaliths, which, if overlooked, may cause failure in healing of the abdominal wound. In no domain of surgery are gentleness and care more necessary than in the operative therapy of perforated appendicitis. *Abdominal packs* should be used with great care and gentleness because they traumatize intestinal loops and tend to spread infection, besides encroaching on the abdominal opening. Contamination is also minimized by removing pus as soon as encountered, with a suction apparatus if possible. Postoperative complications, particularly intestinal obstruction, may, in general, be minimized or completely avoided by an adequate incision and gentle *handling of the peritoneum and intraabdominal viscera.*

The question of drainage in operations for acute appendicitis must be decided at the time of operation. The principles upon which drainage is based was emphasized years ago by Yates. A drain is used, in general, because the surgeon wishes to create and maintain an open wound so that any excessive infection or source of contamination may reach the outside rather than become enclosed in the depths of the wound and thus lead to the danger of a local abscess or of a spreading peritonitis. *A drain is not needed* when the appendix is not ruptured. If a local peritonitis or an abscess is present some surgeons feel safer with the area exteriorized with drainage. In severe cases, drainage may

possible conditions should always be suspected as the cause of the abdominal symptoms.

TREATMENT. Careful clinical study has shown that relief of symptoms has been consistently achieved by appendectomy in those patients in whom the resistance to flow through the appendix into the cecum has been elevated. Relief has frequently not been achieved by appendectomy in this entire group of patients, including many in whom the disease process has not been so meticulously demonstrated to be genuinely in the appendix. In some of this latter group, the pain may even be magnified after the patient leaves the hospital. Careful selection of cases for appendectomy leads to relief of symptoms in three fourths of the cases and thus justifies the diagnosis of chronic appendicitis. The operation, however, should be carried out through a rectus incision, particularly if the patient is a female, so that an adequate abdominal exploration can be done at the same time to detect other possible lesions which may be of clinical significance.

Operations for Appendicitis. Until the part played by the inflamed appendix was discovered, operations for acute appendicitis were performed only for complications. Incision and drainage was carried out for what was clinically called "phlegmon of the abdominal wall" or "right iliac abscess." Because many physicians thought that the suppuration originated in the cecum, a frequent diagnosis was typhilitis or perityphilitis. In many instances, of course, general peritonitis occurred and the attending physician would note no localizing process in the right lower quadrant, and the death certificate in such patients usually carried the diagnosis of "acute indigestion." Needless to say, the mortality was exceedingly high, even when an abscess was opened and drained.

In 1886, a physician, Reginald Fitz (68), after a study of many autopsies, described his findings as "perforating inflammation of the vermiform appendix with special reference to early diagnosis and treatment." This report, along with others in other countries, played an important part in the development of the modern operation of appendectomy in acute appendicitis. Although many previous observers, notably Addison and Bright, as early as 1838, suggested the relation between appendicular infection and "iliac abscess" and general peritonitis, the teachings and observations of Fitz, who was primarily an internist and pathologist and not a surgeon, had a tremendous influence in clarifying the subject, in this country at least, and pointing to the importance of early appendectomy. Surgeons were quick to recognize the importance of these observations, and before the end of the century, many patients' lives were saved by adequate operation. Among others who have contributed to the knowledge of this disease, the names of Charles McBurney, Albert J. Ochsner, and J. B. Murphy should be especially mentioned. Nevertheless, it is true at the present time that failure to perform an appendectomy in acute appendicitis, especially before perforation has occurred, is still the most common yet avoidable cause of the considerable mortality in this disease.

Either of two types of incision is generally used in entering the abdomen for operation in appendicitis (Fig. 25). The McBurney incision is located over the McBurney point, is small and utilizes only the separation of the oblique and transversalis muscles in approaching the peritoneal cavity. Because the fibers of these muscle layers cross each other, this approach is often called the gridiron incision. It has the advantage of requiring less dissection of the abdominal wall, but the disadvantage of permitting only a limited exposure of or access to the peritoneal cavity. The greatest use of it is in the removal of the acutely inflamed appendix which is known to lie in normal position.

When the diagnosis is uncertain, preferably and widely employed is the low right rectus (low right median) incision, in which the right rectus muscle is split longitudinally (separated from its sheath medially) and retracted laterally. This incision may be extended as much as necessary and permits adequate exposure, thus requiring a minimum of intraperitoneal trauma. In "chronic" appendicitis, this incision is particularly indicated since it permits inspection and palpation of the other abdominal viscera. Exploration should be an essential part of the operation if there is even the slightest doubt as to the appendicular origin of the patient's pain. It is practically impossible to gain any information

bowel movements is usually important, especially if there has been a sudden change. In certain cases, delayed motility can be assumed if the patient notices increasing difficulty in passing stool, relieved only by the use of cathartics. Accurate measurements of colonic motility, however, can be made only by special methods, including the use of the x-ray.

Just as important as the motility of the colon is the character of the stool, the consistency, the color, the shape and particularly the appearance of gross blood. Many patients are entirely unaware of such changes because they do not or cannot inspect the stool after defecation. In such cases, negative statements are obviously of no value. On the other hand, accurate observation as to alterations in the appearance of the stool may, in many cases, prove of considerable diagnostic value. For example, tarry stools in the absence of medication, such as iron, may be an indication of bleeding high in the alimentary tract. Fresh blood obviously indicates an ulcerative lesion, benign or malignant, in the distal portion of the colon, although occasionally in the presence of extreme hypermotility such blood may originate from the duodenum. Many disturbances may produce melena, the differential diagnosis of which has been ably discussed by Gray and associates (70), based upon extensive clinical experiments of many types of cases. Acholic stools, particularly when the patient has not ingested a great deal of milk, is evidence of obstructive jaundice. Hard, marblelike feces, or narrow ribbonlike feces are usually associated with spasm of the colon, only rarely by a narrowing of the lumen. Frequent liquid stools, often referred to as diarrhea, may be due to extracolonic causes, but are often a manifestation of inflammatory, neoplastic, or functional disease in the colon. Mucus and pus are found in ulcerative disease, both inflammatory and neoplastic. Mucus alone may be present in purely functional disease, notably spastic colitis. Parasites of various types may be noted grossly, but microscopic search of the feces for their larvae will be a more accurate method. This is particularly true of amebiasis, proper facilities for the examination of which with a warm stage microscope should be available to all physicians. It is essential to this examination that the stool be freshly passed (one hour maximum).

Disease of the colon produces pain which is rarely specific in nature and occurs both in medical and in acute surgical diseases. The colon is well supplied with autonomic nerve fibers which may carry impulses of pain, of a poorly localized type. The pain may be referred to the anterior portion of the abdomen or to the back. The abundance of autonomic innervation may also explain the frequency of functional diseases which masquerade as organic lesions of the colon, and make the problem of diagnosis and treatment especially difficult.

Physical examination of the abdomen is obviously important in the diagnosis of diseases of the colon but is frequently of limited value. Although the transverse colon, cecum, and sigmoid are the most accessible to palpation and may reveal masses due to carcinoma, tenderness due to acute inflammation, or a hard tubular sensation characteristic of spastic colitis, very often the examination is entirely negative. It is because of inadequacies in the usual history and physical examination that special examinations are essential in the diagnosis of disease of the cecum and colon. The sigmoidoscope, which enables direct vision of the distal part of the colon, is described later in this chapter. It should be used routinely in the diagnostic study of gastrointestinal disease. More important, however, is the expert fluoroscopic and radiologic study of the cecum and colon after a barium meal ingested some hours before or with a barium enema. More recently, air contrast barium enemas have been added to the radiologic examination, and may reveal diseases not possible with the ordinary routine, particularly when carried out by experts. As mentioned above, laboratory examination of a fresh specimen of feces may be of great diagnostic value.

Chronic Constipation. Fecal stasis, or a delay in colonic motility is a more descriptive term than constipation and should be based upon other evidence than the mere statement of the patient himself. The frequency of bowel movements is, of course, the most important clinical evidence thereof, particularly if the patient has such difficulty

persist for two to three weeks. Occasionally, a fecal fistula follows operation for perforated appendicitis; in such instances, the fistula usually closes spontaneously unless an associated obstruction is present distal to the opening in the intestine.

Combined chemotherapy, though discussed elsewhere under the treatment of peritoneal infections, is mentioned here also because it has greatly reduced the indications for drainage. Unless there is a likelihood of fecal leakage or there is extensive irremovable necrotic tissue, most surgeons do not employ drainage, for it tends to increase the length of hospitalization. There is no evidence that the incidence of residual abscesses is reduced by drainage. As already mentioned, chemotherapy has also greatly reduced mortality and postoperative complications in patients with peritonitis. The use of a combination of bactericidal drugs, such as penicillin and streptomycin, gives a much greater antibacterial coverage than one alone, which is important because of the frequency of mixed infections in the severe cases. It is now a frequent experience for patients seriously ill with peritonitis from a perforated appendix to enjoy a relatively uneventful postoperative course following appendectomy.

Tumors of the Appendix. Tumors of the appendix are rare and are found usually at the time of operation carried out for chronic appendicitis or as an incidental appendectomy performed during the course of other abdominal operation, notably cholecystectomy. Carcinoid tumors of the appendix are apparent grossly as a slight to moderate enlargement of the organ which is firm in consistency. Carcinoid tumors may occur in all parts of the gastrointestinal tract, and may be malignant, although those located in the appendix are usually benign. A recent study contains many details and a review (49). Metastases in the malignant cases are usually referred to as carcinoidosis, and may be detected clinically by the appearance of diarrhea and periodic "flushing" of the skin, and by finding an increased output of serotonin (5-hydroxyindol acetic acid) in the urine (69). *Mucocele* is due to chronic low grade obstruction and is not a true neoplastic process; it is not infrequent and may be a rare cause of chronic appendiceal pain. Sympathetic *neuroma* in the appendix has been described in Chapter 27. True *carcinoma* of the appendix is likewise infrequent and may or may not produce specific clinical manifestations, dependent upon the rapidity of growth and involvement of the cecum. Either carcinoid or carcinoma, if located proximally in the appendix, may obstruct the lumen and lead thereby to acute appendicitis.

THE CECUM AND COLON

The large intestine is generally subdivided into two regional groups, the colon (including the cecum), which is discussed under the above heading and the rectum (including the anus), which is considered separately. The cecum and colon are the sites of a number of surgical diseases, the most serious of which is carcinoma. There are diseases which are best treated without operation and which simulate those requiring surgical intervention. Differential diagnosis is important and often difficult. Although abdominal pain is a frequent manifestation of colonic disease, it is often insufficiently characteristic to be of differential value. More frequent manifestations are due to alterations in the character and nature of the stool. This information, as well as knowledge of the character of the feces is an important part of the diagnostic data. Too often, in obtaining a routine history, this information is inaccurately or incompletely obtained or carelessly overlooked entirely.

Evidence of delay in colonic motility is of surgical importance in that changes in bowel habits from normal to constipation may be indicative of increasing obstruction. Such a delay is often unaccompanied by pain until the obstruction is complete. Even then the acute pain is seldom as severe as that encountered in obstruction of the small intestine. Details of intestinal obstruction in the colon are described in Chapter 33.

Changes in function of the large bowel are usually indicated by a change in the motility of the colon and are usually described rather poorly by the patient as either constipation or diarrhea, terms which may be misleading and really should not be used without a more exact and detailed description of what they mean. A statement as to the *frequency* of

In slightly more than half the cases diarrhea, usually of a very serious degree, develops almost simultaneously. The stools are voluminous and watery. Shock with a drop in blood pressure is common. Fever is present in most cases. Culture reveals a micrococcus pyogenesis in most cases, and frequently almost in pure culture. This floral change is presumably caused by a previous or current use of antibiotics. The chief pathologic feature is a pseudomembranous lesion associated with other evidence of severe bacterial inflammation. Sensitization tests should be made on the micrococcus and the indicated antibiotics given, although much more effective is the use of enemas of a suspension of fecal material.

Polyps. Most common in the sigmoid and rectum, these pedunculated tumors, really *adenomas*, are either single or multiple; when present in large numbers, the condition is referred to as polyposis. Polyps may give rise to bleeding, diarrhea, and abdominal pain. Diagnosis may be made by radiography following a barium enema, especially with the air contrast technic. If situated in the rectum or lower sigmoid, they may be directly visualized with a proctoscope or sigmoidoscope. Since they have a definite tendency to undergo malignant degeneration, excision and careful follow-up are necessary. Rectal polyps may be removed through a proctoscope, whereas those higher up will require an abdominal operation after adequate preparation of the colon. Segmental resection of the colon including the polyp is definitely indicated should the polyp show a broad base or gross evidence of malignancy. After removal of the polyp, the rest of the colon should be examined for other polyps. This will be aided by inspection of as much of the interior of the colon as possible with a sterile proctoscope.

Multiple polyposis may occur as an inherited disease which has a high incidence of malignant degeneration even early in life (Fig. 26). For this reason it is usually advisable to resect the colon as soon as the diagnosis is made in order to prevent the malignant transformation (78). In such cases, the rectum may be preserved providing all the polyps are removed through proctoscopy at the time and during subsequent repeated observations (79). Removal of the rectum, however, may be necessary when this is not possible, or when the polyps in the rectum are too numerous. Even then, anastomosis between the ileum and anus may be performed, and will preclude the need for a permanent ileostomy (75).

Carcinoma of the Colon. Carcinoma of the colon and rectum accounts for over one tenth of all deaths due to malignant disease. The neoplasm is usually an adenocarcinoma and may be either a bulky, fungating growth, filling the lumen of the bowel, or scirrhous in type, encircling the wall in the form of an annular stricture. Colloid carcinoma, though rare, also occurs, particularly in the cecum, and is prone to perforation and abscess formation. Metastases occur by way of the lymphatics to the mesenteric lymph nodes and by way of the portal vein to the liver or beyond the liver to the systemic circulation, involving lung, bones, brain, and other tissues. The tumor grows at any point in the colon, but increases in frequency as one proceeds from the cecum, being most common in the sigmoid and rectosigmoid portions.

Clinical manifestations will vary with the location of the tumor and the rapidity of growth. Right-side tumors tend to produce bleeding and anemia, weight loss, and a palpable mass. Pain often occurs and is sometimes mistaken for acute appendicitis, for which appendectomy is occasionally undertaken. In exploration for supposed appendicitis in which the appendix appears normal at operation, therefore, the surgeon must examine the colon for tumor in the course of his search for the cause of trouble. In the left colon, the diameter of the bowel is much smaller and the content is regularly more firm; cancer here is therefore more likely to lead to obstruction. Obstruction may be manifested by gradually increasing meteorism and difficulty at stool, or may appear abruptly and full-blown with few or no antecedent manifestations.

Early in the disease, symptoms may be limited to evidence of ulceration or low grade obstruction, which should always arouse a suspicion of cancer in an individual of middle or older age. Early evidence of ulceration is the appearance of blood and mucus in the stools, or of frequent liquid stools; early evidence of obstruction consists of increasing

as to require the use of cathartics. As mentioned above, this condition is of diagnostic significance in surgical diseases, at least when it appears suddenly without warning in an individual who has previously had normal bowel habits. It is such a common condition that the surgeon should acquaint himself with some of the features and the therapy.

Spasm or atony of the colon may be the cause of fecal stasis; the terms *spastic constipation* and *atonic constipation* are applied to these conditions. Spastic constipation must be recognized by the surgeon lest the associated pain lead him to the erroneous diagnosis of a surgical lesion.

Tuberculosis. About half of all intestinal tuberculosis is said to occur in the cecum. Over one third of all patients with pulmonary tuberculosis are believed to have demonstrable lesions in the alimentary tract. Most patients with tuberculosis of the colon also have an active lesion in the lung. Of great import surgically is tuberculous ulceration of the cecum, a lesion accompanied by annular ulceration and secondarily by fibrous thickening of the wall, producing symptoms and signs which may at first be indistinguishable from those provoked by carcinoma. Fortunately, tuberculosis of the gastrointestinal tract is becoming a rare condition, along with the gradual disappearance of other forms of tuberculosis.

Abdominal pain, diarrhea, and blood in the stool are the chief manifestations. In the early cases, pain is the only symptom, which may simulate mild appendicitis, and lead to an operation. The surgeon in such a case should be a good enough gross pathologist to recognize the true nature of the disease. In other untreated cases, stenosis will ensue, which may be sufficient to produce a partial obstruction.

Diagnosis is readily made roentgenologically with the aid of a barium meal and/or enema. The deformity noted by x-ray may be identical with that produced by carcinoma, but the extreme irritability of the cecum is often characteristic. Pulmonary tuberculosis should always be looked for. Operation for removal of the lesion may be indicated if severe symptoms are present. Medical therapy, especially with streptomycin and associated drugs, is preferable.

Ulcerative Colitis. This disease is a definite pathologic and clinical entity of unknown etiology. It may initially produce abdominal pain which simulates acute appendicitis, but later the history of chronicity, the presence of diarrhea, blood, and mucus in the stool should eliminate any difficulty in the differentiation. On the other hand, it may be confused with the manifestations of carcinoma. Very important in the differentiation is expert radiologic and proctoscopic study. Treatment is a medical problem, at least at the onset, and includes attention to dietary and psychogenic factors (71). Unfortunately, some cases do not respond to medical therapy and develop complications or recur so frequently that surgical intervention is indicated.

Surgical therapy is being used more and more because of the increase in the number of cases which do not respond to medical therapy, the danger of cancer, and the development of complications such as cirrhosis and arthritis (72), in the persistent cases, and especially because radical surgery has become safe, often lifesaving, and frequently yields dramatic restoration of the patient to relatively normal life even with a permanent ileostomy (73, 74). Complete proctectomy and colectomy is the safest and most effective procedure to employ and is often possible in one stage. An ileostomy may be avoided in some cases by a staged procedure ending with an anastomosis between the ileum and the anus (75), or the rectum may be preserved with anastomosis of ileum to it. Both these procedures carry a higher risk of death and of unsatisfactory functional result than proctocolectomy does. Total colectomy is usually an elective procedure, but may be urgently needed as an emergency in the face of acute perforation or of fulminating toxicity not responsive to medical means. Segmental ulcerative colitis, which may be related to regional enteritis, has also been described and may rarely respond to less extensive operation (76).

Pseudomembranous Colitis. This is an uncommon but serious disease of the colon occuring almost always after operations in the abdominal cavity. In almost half the cases (77) the operation has been performed for carcinoma of the colon. Cramping abdominal pain, nausea, vomiting, and distention are the most common early symptoms.



Fig. 27 Carcinoma of the colon. Note the characteristic filling defect adjacent to the hepatic flexure following a barium enema. The x-ray was particularly helpful in this case inasmuch as the history of abdominal symptoms was vague, consisting merely of anorexia, moderate loss of weight and slight upper abdominal tenderness. At operation the tumor was found and a resection of the colon performed (see Fig. 28) in two stages according to the Mikulicz technic. 10 years have elapsed since operation and the patient, now 67 years old, is well, asymptomatic and carries out her duties as housewife.

colostomy and to postpone resection and anastomosis for the second stage. During resection, care is necessary to avoid manual massage of the tumor, which has been shown (80) to dislodge malignant cells into the lumen of the bowel with possible implantation into the suture line, and into the portal stream to be carried to the liver. Wide excision with ligation of the vein and artery to the excised segment as the first step will ensure against leaving cancer cells. Further details, including the results of surgical therapy, will be found in several reports (81, 82, 83).

Diverticulitis. Diverticula in the colon are common after 45 years of age and are usually diagnosed during routine radiologic examination with barium as multiple rounded shadows (diverticulosis). Occasionally, they become inflamed and produce symptoms of diverticulitis (pain, cramps, diarrhea) which are usually mild and transient. Serious manifestations are due to perforation, obstruction, or bleeding. The clinical picture of acute diverticulitis may be that of acute appendicitis located in the left instead of the right lower quadrant because the diverticula are nearly always located in the sigmoid colon. The inflamed diverticula may perforate into the peritoneal cavity and produce a local peritonitis or abscess. Bleeding per rectum or signs of colonic obstruction and other manifestations will simulate carcinoma (84).

Treatment of acute diverticulitis depends upon the complications produced. If an acute perforation has occurred with signs of spreading peritonitis, operation will be necessary. The procedure to be followed is clo-

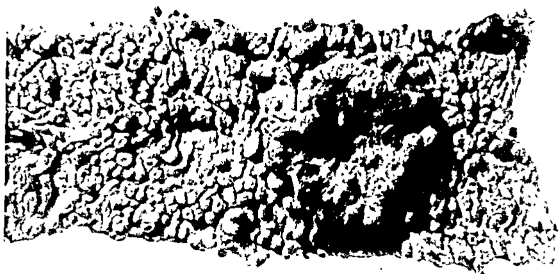


Fig. 26. Multiple polyposis of the colon. In this patient, a male aged 32, there was a history of frequent stools for many years; during the past six months they had been mixed with blood. Examination of the resected specimen reveals an ulcerating carcinoma which presumably started in one of the polyps.

difficulty in regular defacation and attacks of cramping abdominal pain. Frequently, periods of obstructive and ulcerative symptoms alternate. Such manifestations, unless explainable in some other way, call for *investigation of the colon* by radiologic means. Diagnosis in this way may frequently be achieved early in the disease (Figs. 27, 28). In tumors of the distal colon and rectum, direct visualization with a sigmoidoscope is usually possible, and a biopsy may be obtained for histologic verification.

Loss of weight, acute intestinal obstruction, and severe anemia sometimes, but not always, mean an advanced lesion and unfortunately are occasionally the first clinical indication of disease. Usually, however, a period of weeks or months of lesser symptoms precede them, and it is during the earlier period that diagnosis should be made in order to institute hopeful therapy. It cannot be emphasized too strongly that change, sudden or insidious, in the pattern of gastrointestinal behavior of a patient past 40 years of age should demand a careful study for cancer of the colon, rectum, or stomach.

Treatment is wide resection of the tumor, together with the adjacent mesenteric lymph nodes. This is most safely done after adequate preparation, which includes chemotherapy. If there is no obstruction, the tumor may be excised and a primary anastomosis performed at one stage. In the presence of obstruction in the right colon, aseptic operative decompression, primary resection of terminal ileum, cecum, and colon to the midportion or left portion of the transverse colon, together with all possible mesentery and omentum, is the procedure of choice. Primary end-to-end anastomosis is in order. In the presence of obstruction in the left colon it is safer to perform a preliminary



Fig. 27 Carcinoma of the colon. Note the characteristic filling defect adjacent to the hepatic flexure following a barium enema. The x-ray was particularly helpful in this case inasmuch as the history of abdominal symptoms was vague, consisting merely of anorexia, moderate loss of weight and slight upper abdominal tenderness. At operation the tumor was found and a resection of the colon performed (see Fig. 28) in two stages according to the Mikulicz technic. 10 years have elapsed since operation and the patient, now 67 years old, is well, asymptomatic and carries out her duties as housewife.

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Fig. 28. Carcinoma of the colon. Gross and microscopic appearance of resected specimen in the case described in Fig. 27. The rectangular area at the edge of the ulcer represents a block of tissue which was removed for microscopic section; note how it includes normal as well as diseased tissue. The photomicrograph shows clearly the difference between the normal epithelium of the colon (at the top) and the malignant tissue, i.e., adenocarcinoma (below).

sure of the perforation with a "patch" of omentum, inasmuch as it is usually difficult to close it, aided by colostomy to relieve the obstruction in the colon which is usually associated with the inflammation at the site of perforation. A transverse colostomy is also indicated if operation is performed for acute obstruction without perforation or for the drainage of an abscess. In such a case, the differentiation from carcinoma will be difficult (84) but obviously important because of the difference in further therapy. The subsequent use of the x-ray following a barium enema will often be helpful. In most cases of diverticulitis the obstruction subsides; however, resection is indicated when carcinoma is suspected or when a fistula persists. Large abscesses resulting from perforation require drainage. Occasionally, perforation occurs slowly into adjacent organs and leads to a fistula into the bladder, cervix, or vagina. In such cases, too, resection preceded by colostomy will be the procedure of choice. The various surgical implications of diverticulitis have been well described by Allen (85).

The lesser and more chronic types of diverticulitis may produce pain and diarrhea and, in occasional cases, bleeding. The diagnosis is usually made after careful study by radiography and occasionally by sigmoidoscopy. In most cases medical care is sufficient, but resection may be required in the persistent cases. Welch's studies show that difficulty with diverticulitis before the age of 45 or 50

is followed by rapidly increasing troubles and that early elective resection is the prudent therapy.

Miscellaneous Diseases of the Colon. In the older literature, much attention was paid to the condition known as visceroptosis. The term refers really to an abnormal mobility due to a long mesentery. For this reason, when the patient stands, his viscera tend to drop toward the pelvis. It is doubtful whether this condition produces significant symptoms, although the redundant and mobile sigmoid may be responsible for the development of volvulus with signs of acute strangulation as discussed in Chapter 33. Operations for the correction of visceroptosis are no longer performed; the condition is generally considered to be normal for certain hyposthenic types of individuals.

Actinomycosis of the colon occurs really in the cecum and has a distinct propensity to produce symptoms similar to any of the ulcerative lesions already mentioned, including perforation. Actinomycosis, however, has a tendency to produce a chronic mass and multiple fistulous openings to other viscera or to the outside. The diagnosis is made by finding the ray fungus in a freshly opened abscess (see p. 109). In the past, treatment was unsatisfactory in the late stages, but now, if an early diagnosis is made, incision and drainage of the abscess, or excision of diseased tissue, combined with chemotherapy (e.g., sulfadiazine and *heavy* doses of penicillin), and radiotherapy, is usually effective.

Foreign bodies may become lodged in the colon after ingestion, although most of them will be passed in the stool. Should passage become arrested, which is most frequent in the hepatic or splenic flexures, symptoms of mild obstruction may follow. More commonly, if the object is sharp, a slow perforation may lead to the production of localized peritonitis, followed usually by an abscess. Occasionally, abscesses adjacent to and attached to the colon are encountered at operation when no primary source can be found. Preoperative diagnosis is usually appendiceal abscess or abscess due to diverticulitis. Should a foreign body be located at the time of operation, the cause is obvious. Drainage may be followed by a chronic sinus or intestinal fistula, which may require subsequent therapy. Although the swallowed foreign body is usually a toothpick or sharp bone, a history of swallowing it is seldom obtained.

Megacolon has been discussed on page 650.

Congenital anomalies are extremely rare and consist of stenosis or atresia. They are usually associated with similar lesions in the small intestine, as discussed in Chapter 33.

RECTUM AND ANUS

Carcinoma is the most serious disease of the terminal large bowel; hemorrhoids and inflammatory lesions, such as proctitis, cryptitis, ischiorectal abscess and fistula-in-ano, are the most frequent, and are important because they often cause serious disability.

Despite the frequency and seriousness of diseases of the anorectal region, they suffer more from neglect than any other group of lesions. Common inflammatory lesions are responsible for considerable loss of time at the office, the shop, and in the home. Carcinoma, which is so readily diagnosed, is frequently seen only in the late stages of the disease when hope of curative surgical therapy is greatly reduced. Many patients suffering from rectal diseases visit the pharmacist for relief. In no other field of disease has the charlatan and the purveyor of quack remedies so exploited the public.

The members of the medical profession themselves are almost entirely to blame for this situation, first because they have only recently accorded adequate attention in the medical curriculum to study and teaching of anorectal diseases. Moreover, the practitioner himself has been responsible because of his failure adequately and thoroughly to examine this part of the body either during the routine physical examination or even when the patient presents symptoms referable to this area. Although the rectal cavity is really just as accessible to inspection and palpation as the oral cavity or vagina, few physicians carry an anoscope in their bags or even maintain one in their offices, even though they are well supplied with vaginal specula, not to mention, of course, tongue depressors, auroscopes, stethoscopes, and even opthalmoscopes. The easiest and simplest method of making a diagnosis of rectal

cancer is with the palpating finger, yet rectal examination is often neglected even during an otherwise thorough physical examination.

Methods of Examination and Diagnosis. Inspection of the anus and rectal palpation with the gloved finger should be part of every routine physical examination. In addition, every patient complaining of anorectal symptoms should be given a more complete local examination, in addition, of course, to a complete history, which alone may lead to the diagnosis.

In the history of a patient suspected of anorectal disease, the following questions are especially important. 1. Is there, or has there been any change in bowel habit, such as a definitely increasing constipation or persistent tendency to diarrhea? 2. If the patient has inspected the stool, has he noted blood or blood-tinged mucus from the rectum, or has he noted blood on the toilet paper? 3. Has the patient had persistent pain in the perineum or in the anus either during or after defecation? 4. Has pus ever been noted on inspection of the stool? 5. Has the patient ever noted a protrusion or external swelling, and if so, is it permanent or does it reduce spontaneously, or can it be reduced after each bowel movement? The anorectal area should be suspected in pain referred to the posterior perineum and coccyx.

Simple inspection of the anus after gently spreading the buttocks apart will frequently reveal a fissure, an external thrombosed pile, or the opening of a fistula or a pointing ischiorectal abscess. Digital examination is next, but may be impossible or postponed if there is severe anal spasm or exquisite tenderness. No digital examination is made without a rubber glove for the protection of the physician himself. The finger cot is an inadequate safeguard in patients with syphilitic or other infectious anorectal diseases.

The best position for anal and rectal examination is with the patient lying on the left side, or still better, in the prone knee-chest position. Good illumination is essential. The well-lubricated gloved finger is gently pressed against the anal opening and painful points, if present, detected by palpation at regular intervals around the periphery of the anus. The posterior commissure is the most frequent site of painful lesions. The patient should be assured that the examination will be gentle, and that it will be terminated on the slightest indication of pain. By such reassurance and *extreme gentleness,* contraction of the anus can be readily overcome and the examining finger introduced without further difficulty. This is often aided by asking the patient to strain. The tone of the muscle is first noted. The healthy sphincter which relaxes under digital examination and fails to contract over the finger, tiring rapidly into a state of relaxation, suggests a diagnosis of tabes dorsalis, syphilis of the central nervous system, or tumor of the spinal cord. The prostate is next examined and the size and consistency noted. In the female, the firmness and movability of the cervix uteri and other pelvic organs may be observed. In virgins and in children, the rectal finger aided by the abdominal hand permits excellent bimanual pelvic examination. The coccyx too should be examined during a rectal examination, palpating it between the two index fingers, one in the rectum and one over the coccyx. The examining finger then measures the mobility of the rectal mucosa, the size of the rectal ampulla, and the possibility of stricture, polyps, growths, foreign bodies, and impaction, as well as the general consistency of the stool. It should be emphasized that fully half of all carcinomas involving the rectum can be diagnosed by the examining finger.

Anoscopy is an indispensable part of the examination in anorectal disease (Fig. 29). Although in some cases, bowel preparation is necessary, in most instances this is not needed. Should vision be obscured by feces, removal by enema or catharsis will be indicated. The anoscope is an instrument used for the examination of the lower part of the rectum and anal region. It is a hollow metal tube 1.5 to 3 inches long and 0.75 inch in diameter, carrying an obturator with a tapering end which renders introduction easier. The examination, if carried out gently, should cause only slight discomfort. Once introduced, the obturator is withdrawn and with the patient in the knee-chest position, the internal viscera have a tendency to drop forward so that the inrushing air dilates the rectum, allowing one to visualize the interior well up toward the upper limits of the rectal

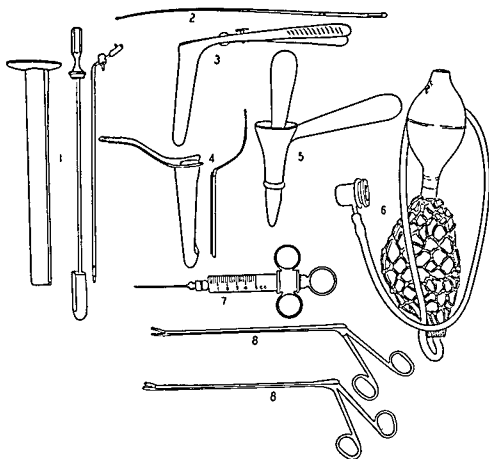


Fig. 29. Instruments ordinarily used in performing a complete anoscopic and proctoscopic examination. 1, proctoscope. 2, flexible probe. 3, bivalve dilating speculum. 4, speculum (Brinkerhoff). 5, anoscope. 6, air dilator and eyepiece for proctoscope; this apparatus is important in the introduction of the proctoscope (see text). 7, syringe and needle for injection of internal hemorrhoids; the needle should be of small caliber. 8, biopsy forceps for removal of tissue through the proctoscope.

ampulla. Carcinoma as well as benign polyps or other low-lying growths can in this way be seen and even biopsied. The lumen of a low rectal stricture can also be seen. Hemorrhoids cannot be seen until the anoscope is withdrawn to the anorectal line. With the sphincter thus dilated, aided by slight straining by the patient, internal piles quickly prolapse into the lumen of the anoscope and frequently drop outside the anal sphincter as the instrument is withdrawn. A careful inspection through the anoscope under direct light may reveal the internal opening of rectal fistulas and diseased rectal crypts, enlarged rectal papilla, and all the various conditions, including fissure, in the anorectal area. The anoscope should really be part of the instrumentarium of every physician. Failure to use it is the most important cause of errors in the diagnosis of anorectal lesions.

Visualization and inspection of the upper rectum and sigmoid requires a longer apparatus provided with a light. The proctosigmoidoscope is a hollow metal tube from 9 to 10 inches in length, provided with a tapering obturator to aid passage through the anal sphincter. It is provided with an air pressure device to dilate the rectum and sigmoid, which aids in the passage of the instrument under direct visualization and in the better observation of the interior of the bowel. The proctoscope is a safe instrument when properly used, but may be dangerous when carelessly used. Every physician should be trained in the use of this instrument and should learn certain simple rules to eliminate

any danger from the procedure. He should learn a definite routine to assure discovery of all lesions that might be found by proctoscopy. It is highly important to place the patient in the knee-chest position or on a modified table that permits the body to recline face down with the chest fairly dependent. The proctoscope should first be thoroughly lubricated, warmed to body temperature and introducted just past the sphincter muscle, at which point the obturator is withdrawn. Here, under direct illumination, the first observation is made. The lens or eyepiece is then applied and air is introduced until the ampulla is dilated. The instrument is now introduced further under direct vision. This method is safe and should be used in contrast to any blind introduction which carries a hazard of perforation. With wide-sweeping circles the instrument is swung around to examine the mucosa of the entire bowel upward as far as possible. Each rectal fold, of which there are several, called the valves of Houston, should be carefully flattened and examined. With experience, not only can the rectal mucosa be examined, but much of the sigmoid beyond the rectosigmoid junction as well.

The proctoscope permits direct vision in most cases of carcinoma involving the rectum and sigmoid up to 25 cm. from the anus. A biopsy can usually be taken of suspicious lesions containing a sufficient amount of tissue for microscopic diagnosis. In the case of rectal ulcers, the proctoscope permits direct vision and scrapings and swabbings which may lead to the diagnosis of amebic dysentery, even when the stool examination has proved negative, or to identified specific bacteria. Should no cause for blood or mucus noted in the ampulla of the rectum be found, the lesion responsible for this finding must be sought by radiologic examination.

Hemorrhoids. Hemorrhoids, usually called "piles," are probably the most common of all anal disease. Two types are recognized, each quite different in pathogenesis and clinical manifestations, although sometimes associated. External hemorrhoids consist of a bit of redundant skin usually covering a mass of veins not unlike a hemangioma. Internal hemorrhoids (Figs. 30, 31) are usually present in the internal anal canal and may not be evident except during defecation or after anoscopic examination. Internal hemorrhoids also consist of redundant mu-



Fig. 30.



Fig. 31.

Fig. 30. Uncomplicated internal hemorrhoids. The lesion was invisible to inspection until an anoscope was inserted. The hemorrhoids and redundant mucosa seen in the photograph appeared on withdrawal of the instrument. Symptoms consisted of the protrusion at each bowel movement, associated with pain and bleeding. Hemorrhoidectomy was performed with complete relief of symptoms.

Fig. 31. Prolapsed internal hemorrhoids. The hemorrhoids became prolapsed two days previously and could not be reduced. Note the ulceration, edema and inflammation. The pain was severe and required sedatives. The patient was 64 years old and previously had very little difficulty reducing the "piles." Operation was performed with excision of the redundant tissue.

cosa containing multiple dilated veins, but are found on the inner aspect rather than the outer aspect of the anal canal. The pathogenesis of hemorrhoids is not clear. Internal hemorrhoids, when they develop after childbirth, which they frequently do, are probably associated with venous obstruction and stasis. In other cases, they may be induced by excess straining at stool because of constipation and anal sphincter spasm. In many instances there is probably a congenital deficiency in the attachment of the rectal wall to the underlying fascia, thus permitting the redundant mucosa to be carried down into the anal canal during defecation. The pathogenesis of external hemorrhoids is not known.

Internal hemorrhoids may become evident to the patient early as a protrusion noticed particularly after defecation, and often associated with a mild degree of prolapse of the redundant mucosa. Usually the protrusion can be replaced manually by the patient or recedes spontaneously. During defecation there may also be *bleeding*, which is usually slight but may be persistent and sometimes severe enough to lead to secondary anemia. *Pain* is not characteristic and is usually absent except with strangulation outside the sphincter, infection, ulceration, or thrombosis. Pain is apt to be noted during and after defecation, which may leave a sense of soreness for many hours. In other cases, the pain may be persistent and continuous, particularly when severe acute inflammation develops. Constipation is often present because of the associated chronic inflammation, anal spasm, and fear of defecation. Internal hemorrhoids are visible on external examination only when they become prolapsed or protruded. Otherwise the diagnosis depends upon anoscopic examination, as mentioned above.

External hemorrhoids may produce annoyance in maintaining cleanliness, but rarely produce other symptoms unless acute inflammation develops, which usually occurs following thrombosis. *Thrombosis of an external hemorrhoid* is not infrequent; it produces localized pain, which may be so agonizing as to lead to complete disability. The diagnosis is obvious on inspection. Tenderness over the indurated mass may be excruciating.

Treatment depends upon the nature of the lesion and the disability produced. In mild cases, internal hemorrhoids require only a short period of rest, local application of heat, and a bland diet with mineral oil to produce a soft stool. If the patient presents a strangulated internal pile, the mass can often be reduced by gentle manipulation with the well-lubricated gloved fingers, with immediate relief to the patient. Obviously, a thrombosed external hemorrhoid should not be mistaken for a prolapsed strangulated internal hemorrhoid and treated in the same way. Operation for internal hemorrhoids consists of excision of the redundant mucosa and venous network and meticulous suture of the operative site to control hemorrhage and to produce adhesions to the underlying muscle during healing. The suture line of the excised tissue should extend in the longitudinal axis of the anus and rectum, ending as high up as possible and starting just above the mucocutaneous margin. Postoperative pain can usually be avoided if the distal end of the incision is left open, particularly when redundant skin has also been removed. The use of sclerosing solutions, such as phenol or sodium morrhuate, to obliterate small internal hemorrhoids, has been widely used and may be carried out as an office procedure. Should infection supervene, however, complications may be serious. Most surgeons, therefore, prefer to treat hemorrhoids by excision.

External hemorrhoids require treatment only when they become inflamed or thrombosed or bulky enough to preclude cleanliness. In the thrombosis, the acute pain located in an external tab can be completely, immediately, and dramatically relieved by a simple excision of the overlying skin and evacuation of the clot. This may require novocain anesthesia, but in most cases there is a sufficient area of skin deprived of blood supply and therefore insensitive enough through which the small incision can be made. Such an incision is not large enough to require a suture, and very rarely bleeds significantly. If the patient is seen 24 hours or more after the onset of the thrombosis, such a procedure cannot usually be performed, due to the organization of the clot.



Fig. 34. Ischiorectal abscess. The patient, a 40-year-old male, had had symptoms for four days. The local pain was so severe that defecation was impossible. After incision about 50 to 75 ml. of foul pus were evacuated. The cavity was adequately opened; it drained for four weeks and closed permanently. In a large majority of such cases a fistula-in-ano will develop. No communication between the abscess and rectum was apparent at operation. A, before operation; B, after being draped; C, after incision.

eral anesthetic is to be preferred. An adequate opening to expose all of the cavity is essential and is made in a radial direction from the anus. To prevent formation of a fistula-in-ano, the abscess cavity should be packed wide open so that healing can take place from below before the opening in the skin heals. Chemotherapy will be helpful in decreasing the possibility of fistula formation.

Fistula-in-Ano. An ischiorectal abscess nearly always precedes the formation of fistula-in-ano. The effective use of chemotherapy has undoubtedly reduced the incidence of this complication. Frequently there is a history of spontaneous healing followed by reformation of an abscess. Occasionally the infection may spread throughout the tissues of the perineum and produce numerous fistulous openings, which communicate with each other. Even when only one opening is observed, the tract may be long and tortuous. Some cases are associated with stricture of the rectum. The symptoms, aside from recurrent abscess formation, may consist of nothing more than a continuous discharge from the wound, which thus requires constant dressings. When the tract drains inadequately, pain and systemic evidence of infection may occur. A slight difficulty in moving the bowels is often present, sometimes accompanied by pain.

The fistulous tract may be simple or complex (Figs. 35, 36). Sometimes the communication with the rectum is absent or microscopic. When no internal opening is present, the term *blind fistula* is used. A *complete fistula* has two openings extending completely from mucosa to skin at any level. The relation of the fistula to the external and internal anal sphincters is important. Some are distal to the sphincters and thus entirely subcutaneous; others pass between the internal and external sphincters to enter the anal canal. *Internal fistula* is the result of an abscess which has broken into the rectum only. Variable, too, is the directness of the fistulous tract; nearly all are tortuous and burrow extensively, sometimes halfway around the circumference of the rectum, before they end. When more than one external opening is present, they lead to tracts which are continuous. The chronicity of the lesion and the failure to heal, in most cases, is due to the continuous exposure to infection from the rectum. In other cases, when the opening is blind, other factors, including especially insufficient drainage, may play a role; certain of them are tuberculous, and microscopic or cultural evidence thereof is obtainable, and when it is, most (75 per cent) of the patients are found to have demonstrable active or arrested pulmonary tuberculosis. A significant proportion of patients with pulmonary tuberculosis, moreover, suffer from anorectal infections.

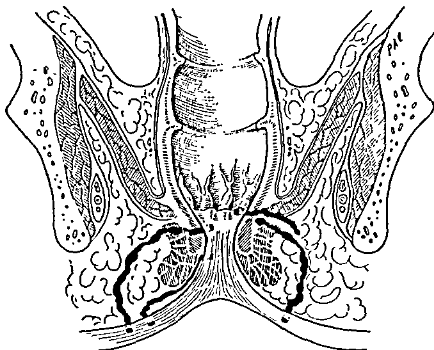


Fig. 35. Diagram showing four varieties of fistula-in-ano. The two on the left are complete and have two openings; one of the tracks opens above, and the other below the sphincter. The two on the right are "blind," in reality, therefore only sinuses, that one above an internal, the one below an external blind fistula. It is believed, however, in the case of the external blind fistula an internal opening does actually exist but is so small that it is not demonstrable.

Treatment requires operation, although well-selected chemotherapy is probably useful during the postoperative period. Excision is preferable to merely laying the tract open to allow granulation from below. If the tract passes deep to the external sphincter, this can be singly divided without significant loss of continence. If the tract passes deep to both the external and internal sphincters, division of both of these muscles is improper, as it will lead to incontinence. The recommended procedure in this circumstance is to open the tract widely with preservation only of the continuity of the internal sphincter, about which a loop of heavy suture material is loosely tied. At a second stage, two weeks later, the fibrosis induced by the presence of this seton will permit complete opening of the tract by division of the internal sphincter, without loss of continence. The wound in any case must be daily dressed and packed open to ensure healing from the bottom, without pocketing of suppurating foci (Gabriel, 88). The severe cases with multiple external openings, particularly when



Fig. 36. Fistula-in-ano. The patient was a 30-year-old woman who had had symptoms for two years following drainage of an ischiorectal abscess. The opening of the tract can be seen in the skin just below the anus. Injection of methylene blue into the external orifice of the fitsula failed to reveal an internal opening, nor was one demonstrated at operation several days later. The entire tract was excised; its deepest point was at least one centimeter from the rectal wall. Healing was complete.

stricture of the rectum is present and there is extensive perirectal infection, may require a permanent or temporary colostomy. Even if the lesion is tuberculous, cure may be achieved in a large percentage of cases provided careful, effective, and radical surgery is performed.

Stricture of the Rectum. Fairly common among Negro women, this lesion was considered of syphilitic origin, but most recent studies have shown that it is a manifestation of a venereal disease called lymphogranuloma venereum (see p. 111). The infection reaches the perirectal lymphatics through the venereal portal of entry and induces a mild type of proctitis which becomes evident by diarrhea, pain on defecation, and tenesmus. Ulceration may be seen at this stage. Slowly fibrous tissue is laid down, encircling the rectum and leading to a stenosis or stricture. Considerable infection above the stricture is usually present, and pus is passed with each stool, which is necessarily liquid in character. The infection may occasionally be responsible for the development of a perirectal (or ischiorectal) abscess which burrows through to the buttock and forms one or more fistulas which do not heal. Because of the many openings around the anus the term "watering-pot" is often applied. The condition of such a patient is distressing indeed; a colostomy above the sigmoid with the formation of a permanent artificial anus on the abdominal wall is often indicated. When the stricture alone is causing symptoms, progressive dilatation with the finger or rubber bougies of increasing caliber affords considerable relief, although a normal caliber cannot be regained. Radical excision of the involved area, backed by effective chemotherapy, is now feasible.

Polyps. These tumors occur in the rectum as well as in the colon and may be single or multiple. When in the distal colon or rectum, they may be seen through a proctoscope or sigmoidoscope. Polyps may also be detected in the rest of the colon, though with greater difficulty, by means of air contrast barium enema x-ray examination. Clinical manifestations are usually due to the tendency of a polyp to bleed. Polyps of the rectum are a common cause of rectal bleeding in early childhood. Young children may have a succession of polyps which slough off spontaneously in the feces after growing to a moderate size. A polyp near the anus may be mistaken for a prolapsed internal hemorrhoid. The greatest significance of polyps in adults, however, is due to the fact that they are definitely precancerous lesions, although the vast majority remain benign, as shown by the frequency of them in routine autopsies. Since it is impossible to determine clinically whether they are malignant or not, excision is the procedure of choice. When they have a long stalk, they may produce diarrhea and demand removal for symptomatic relief. The type of excision (local or radical) depends on whether they are judged to be benign or malignant.

Proctitis. This represents a medical rather than a surgical problem but produces symptoms which may be mistaken for other lesions. On proctoscopic examination, there are diffuse inflammatory changes in the rectal mucosa, including edema, multiple ulcerations, anemia, or hyperemia. Such changes are usually the visible portion of more extensive lesions higher up in the colon. X-ray after a barium enema will reveal the extent of the disease above the rectum. Proctitis in Negro women is frequently due to lymphogranuloma venereum (see p. 111).

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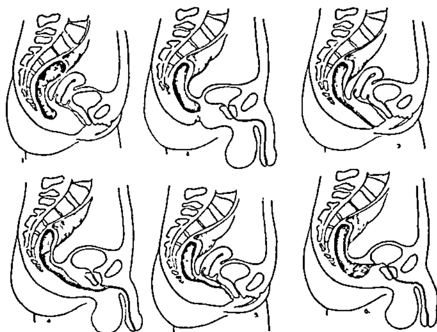


Fig. 37. Types of imperforate anus and the location of the various fistulous tracts formed. 1, absence of anus (proctodeum); 2, fibrous cord attaching rectal pouch and proctodeum; 3, perineal fistula; 4, urethral fistula; 5, rectovaginal fistula, and 6, rectovesical fistula. (From W. H. Cole. Arch. Surg.)

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Some type of operation is indicated, depending on the kind of defect present. When the septum is thin, the skin at the anal sphincter is incised and, by inserting an instrument through the sphincter, the rectal pouch is located and opened. The rectal mucosa is pulled out and anchored to the skin by interrupted sutures. Dilatation at frequent intervals is usually necessary to prevent serious stenosis. If the rectal pouch is high in the pelvis, an immediate abdominoperineal repair has many advantages and is now relatively safe even in premature infants (90). The fistula, if present, is closed at the same time.

Foreign Bodies. On rare occasions, a sharp bone, toothpick, or other object lodges in the rectum after being swallowed and passed uneventfully through the stomach and intestines. A positive history is helpful if it can be obtained. Acute local pain is the usual complaint; if the object is sharp, it may lodge just proximal to the anus and produce an ulceration or abscess. Diagnosis depends on careful digital and proctoscopic examination. Treatment consists in removal of the foreign body and management of the local infection, if present. On rare occasions, a foreign body, such as a bottle, may be introduced into the rectum by the patient in a demented state. Acute rectal symptoms will be present, but the nature of the trouble will

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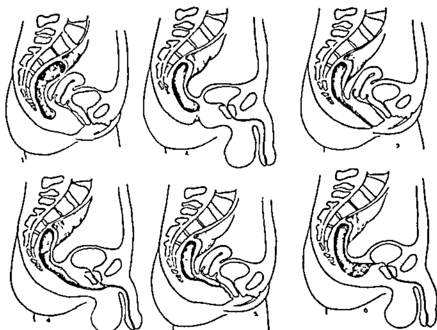


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Fig. 38. Imperforate anus. Roentgenogram of a 12-hour-infant while being held head down. Note the air in the rectum which outlines its terminal end. Fluid levels in the dilated colon can also be seen. An incision was made in the perineum, the rectal pouch located and brought through the sphincter after which the rectal pouch was opened and the edges sutured to the cut edges of the skin.

often be concealed by the patient. Rectal or proctoscopic examination makes the diagnosis. Removal of a large object usually requires a general anesthetic; when the object has been pushed up into the colon and is out of reach, laparotomy will be necessary.

Anal Incontinence. Incontinence of feces (involuntary defecation) may be neurogenic or myogenic. *Neurogenic factors* comprise organic lesions in the spinal cord, such as tabes dorsalis, injury, and neoplasm, and impaired cerebration, which, by releasing the inhibitory mechanism, may result in incontinence; functional as well as organic disease of the brain may be responsible. *Myogenic factors* are produced by injury or disease which has resulted in destruction of the integrity of the sphincters. Injury to the mother in childbirth, extensive inflammatory disease, repeated or radical operative trauma, or congenital absence of the sphincters may be responsible for anal incontinence of this type. It is important to emphasize that special precaution must be taken during operative procedures about the anus in order to prevent injury to the sphincter which may lead to incontinence. This is particularly applicable to operations for fistula-in-ano. The dangerous opinion has appeared in the literature that the internal sphincter may be divided at any one point without loss of continence. This is not the rule, as indicated above. The incontinence may be most prominent only when gas or liquid contents are present in the rectum.

Treatment depends on removal of neurogenic factors, if possible. Functional incontinence may disappear spontaneously or may respond to appropriate psychotherapy. The existence of extensive paralysis means a poor prognosis: careful nursing care is all that can be advised in such cases. When muscle is injured, operative repair by suture of the divided sphincter may be successful. When the sphincter is irremediably damaged or permanent neurogenic factors are responsible, a plastic operation may be advisable (91).

Carcinoma of the Rectum. Adenocarcinoma of the rectum is about as frequent as cancer of the rest of the colon combined. It



Fig. 39. Carcinoma of the rectum. The patient, a 54-year-old female, complained of bleeding from the rectum and pronounced weakness for one year. Rectal (digital) examination revealed a large tumor mass almost filling the rectum. A biopsy confirmed the clinical diagnosis of cancer and a colostomy followed by a perineal resection of the rectum was performed. The gross specimen is illustrated above; microscopic section of the highest lymph node revealed no evidence of metastasis. The two photomicrographs are from the biopsy specimen and show the malignant character of the epithelium. The growth takes a glandular form with irregular, large, deep-staining cells; there is no basement membrane and the growth has penetrated deeply through the wall of the rectum.

occurs anywhere between the rectosigmoid junction and the anus. Cancer at the anal opening is quite different from that of the rest of the rectum, being usually of the squamous type; it is described separately. Adenocarcinoma (Fig. 39), the commoner type of rectal cancer, grows from the surface of the rectum as a cauliflower growth, or penetrates into the wall. In either case, an ulcer forms which bleeds readily; in some instances the growth involves the entire circumference of the bowel, producing an annular tumor. Metastases occur by lymphatic spread posteriorly to the iliac nodes and into the colonic mesentery, or by blood vessels emptying into the portal vein to the liver, or by direct extension. The disease is twice as frequent in males as in females.

At the start, cancer of the rectum may be clinically silent, but in nearly all cases soon produces warning symptoms. *Bleeding* is common and is apt to be slight but persistent; it may be the first symptom noted. Blood passed at stool varies in color, depending

largely on the length of time it remains in the rectum. Though bleeding is most commonly due to benign lesion—that is, hemorrhoids or fissure—this assumption cannot be made without adequate examination, meaning rectal examination and proctoscopy. *Diarrhea* is also a prominent symptom, due presumably to irritation and infection of the ulcerated lesion, but more particularly because the stenosis created by the tumor promotes stasis and, secondarily, putrefaction and irritation of the bowel wall above the lesion. The stools in such instances may be frequent and may contain mucus and blood. *Obstructive symptoms* may be the first manifestations, especially when the tumor encroaches upon the lumen of the rectum, as a cauliflower growth. These symptoms start with increasing constipation or difficulty in moving the bowels, thereby necessitating catharsis. Pain, of a cramping character in the left lower quadrant, and increasing distention also occur. Total obstruction is almost never seen in carcinoma of the rectum proper; when such symptoms arise, the tumor is nearly always located at or above the rectosigmoid. *Change in bowel habits* in an individual past middle age, even if not marked, should be investigated. A sense of incomplete evacuation, looseness of the stool, the presence of blood or mucus, a more frequent desire for defecation, have all been noted by patients who later developed the more evident signs of cancer. However, there are so many other benign and functional or transient disturbances which produce such symptoms that the value of these symptoms lies only in provoking a thorough examination of the rectum. Biopsy should be done when a tumor is present to confirm the diagnosis by microscopic study. *Late symptoms,* such as pain in the region of the sacrum, cachexia, and loss of weight, are sometimes present even in operable cases; development of them therefore is not always a hopeless sign. Ordinarily, however, they signify a far-advanced lesion for which only palliative treatment is possible.

The *treatment* of carcinoma of the rectum is entirely surgical. The results of radiation treatment are not satisfactory. Palliative procedures relieve symptoms but will not prolong life; according to the extensive and excellent studies of Daland, Welch, and Nathanson (92), the average survival without excision of the tumor is about 12 to 18 months. In operable cases without obstruction, the procedure of choice is an abdominoperineal resection in one stage (Miles, 1906) after adequate preoperative preparation. With this procedure, a permanent colostomy is necessary. The results of adequate surgery in favorable cases of cancer of the rectum are gratifying, as shown by five-year survivals of 50 to 60 per cent.

Operation should include an extensive excision en bloc of the tumor, together with most of the high-lying regional lymph nodes. These nodes, as shown by Gilchrist and David (93) and others, are the site of metastases in over half of all cases and must obviously be removed if a cure is to be expected. A two-stage operation is indicated in the presence of obstruction, which is rare in carcinoma of the rectum except in advanced cases. In patients with large and seemingly inoperable tumors, surgeons have occasionally noted, after the colostomy has diverted the fecal stream for some time, that the tumor has become smaller and operable, due undoubtedly to subsidence of associated inflammation.

Carcinoma of the Anus. Malignant disease visible at and involving the anal orifice is rare; it originates outside the mucocutaneous margin and is therefore of the squamous cell type, similar in behavior to squamous cell carcinoma elsewhere. It is a painful lesion, leads to early ulceration, and metastasizes to the regional (inguinal) lymph nodes. Stenosis at the anal canal may occur. Treatment consists of surgical excision of the lesion by the abdominoperineal technic.

Colostomy. An artificial anus in the anterior abdominal wall, now widely accepted, formerly provoked horror in the minds of many patients and a few doctors. The operation, properly carried out with adequate indication, has been responsible for the prolongation of life in relative comfort and a minimum of disability. A colostomy may be placed in any of several sites. A most convenient colostomy is one located just below and to the left of the umbilicus; the bowel emerges through the retracted rectus muscle, which is thought by some to act somewhat as a sphincter. Many surgeons bring the colon

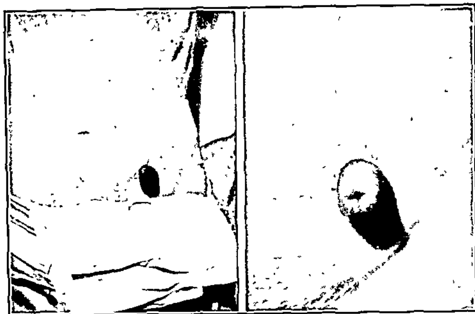


Fig. 40. Single barrel colostomy. A combined abdomino-perineal resection was performed for carcinoma of the rectum three years before. The patient, now 59 years old, works 12 hours a day without disability. In the left photograph above is shown the simple pad which is used to protect the colostomy; an elastic girdle is used to keep it in place. On the right is a close-up of the colostomy. This particular patient has a bowel movement every other day with the aid of small enema, and has complete control in the interval with no escape of gas or discharge.

out through a left lower quadrant (gridiron) incision, as illustrated in Figure 40. With adequate regulation of the diet, a properly performed colostomy will act, with the aid of irrigation, at a regular time every day or two and remain dry during the interval, thus interfering very little with a normal active life. Obviously some type of dressing with a belt must be worn; the old-fashioned colostomy bag is very inconvenient and not needed.

THE UMBILICUS

Because they are rare, diseases of the umbilicus will be considered only briefly. The most frequent lesion is umbilical hernia, which is considered on page 855.

Anomalies. During early embryonic life there is an opening between the primitive gut and the yolk sac which is called the vitelline (omphalomesenteric) duct. This communication is part of the primitive umbilical orifice, which gradually closes by approximation of the margins to form the umbilicus (navel) of extrauterine life. In addition to the vitelline duct, the urachus and the umbilical vessels also traverse the umbilicus.

In adult life, the urachus is represented as an obliterated cord connecting the umbilicus with the dome of the bladder. It arises embryologically from the cranial part of the urinogenital section of the cloaca. The cloaca, which is a part of the hind gut, ultimately separates into a dorsal portion, from which the rectum arises, and a ventral portion (urinogenital chamber), which divides into three parts: 1. the cranial part, which is converted into the urachus; 2. an intermediate part, giving rise to the bladder; and 3. a caudal part, which gives rise to the urethra and, in females, to part of the vagina.

PERSISTENT URACHUS. If the urachus does not become obliterated completely, it may give rise to a sinus which drains seromucoid material through the umbilicus (see below also); if it becomes obliterated at the ends only, a cyst may form. Such cysts rarely produce symptoms unless they become infected. An infected *urachal cyst* produces manifestations of a localized intraabdominal abscess which simulates an appendiceal abscess, except for location in the mid-line between the umbilicus and bladder (Fig. 41). If the infection is serious, drainage of the cavity will be the procedure of choice; however, a sinus

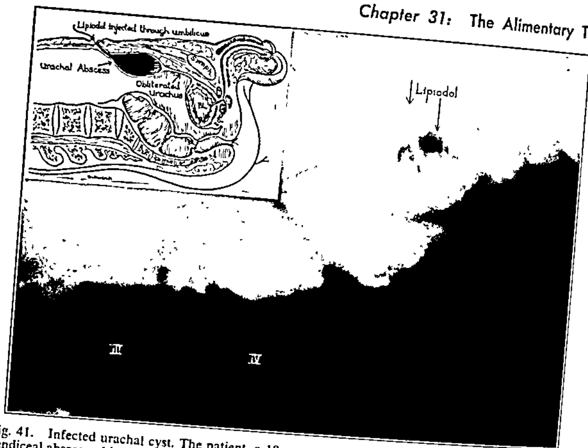


Fig. 41. Infected urachal cyst. The patient, a 19-year-old boy, entered the hospital with a diagnosis of appendiceal abscess which seemed entirely correct except for the fact that the tender area was in the midline below the umbilicus rather than in the right lower quadrant. Several hours later a large amount of pus escaped spontaneously from the umbilicus with complete relief of all clinical manifestations. The illustration above is a print from the lateral x-ray film, made several days later, after the opening in the umbilicus had been injected with lipiodol. Note the detailed diagram in the upper left corner. The patient had no further symptoms. The infection apparently produced a necrosis of the epithelial cells lining the urachus thus allowing healing to occur.

is apt to form which may have to be excised later.

VITELLINE (OMPHALOMESENTERIC) CYST. This anomaly is due to an incomplete obliteration of the terminal end of the vitelline duct, i.e., that part of the yolk sac at the umbilicus; such a defect is noted at birth as a cystic mass at the navel (Fig. 42). On some occasions, these defects may be of a polypoid or adenomatous character; the greater portion of the solid tissue usually consists of structures resembling intestinal wall, particularly mucosa. On extremely rare occasions, the entire length of the vitelline duct remains open, so that an actual communication with the intestine exists, producing a fecal fistula.

MECKEL'S DIVERTICULUM. This anomaly is probably frequent but remains unrecognized unless it produces symptoms (see p. 747). It is, in reality, a part of the vitelline duct but represents the proximal or deep end which enters the primitive gut and which fails to become obliterated completely, thus creating a permanent pouch or diverticulum in the distal portion of the ileum. Part of it may persist in the umbilicus, and, if it contains gastric mucosa, this mucosa will lead to a persistent discharge (see below).

Omphalocele or congenital umbilical hernia of the cord is described elsewhere.

Infections. The umbilicus may become infected after birth due to contamination and lack of cleanliness during delivery. More commonly the infections at the umbilicus occur in childhood or adult life as a type of *dermatitis*. The clinical manifestations include itching, slight pain, and discomfort, and particularly a chronic discharge of mucopurulent material. Inspection of the depths of the orifice will usually reveal a low grade type of superficial skin infection, often as-



Fig. 42. Vitelline cyst. The patient was an infant six weeks old. Methylene blue injected into the cyst emerged from the rectum a short time later. Note redundant tissue as well as the cyst. Treatment was conservative; however, the infant died later of a paratyphoid infection. (St. Louis City Hospital.)

sociated with tiny ulcers. Treatment is usually effective and in most cases leads to prompt healing; simple cleanliness and daily irrigation of the umbilicus with diluted hydrogen peroxide or boric acid solution, followed by careful drying of the invaginated skin, is all that is necessary. If such simple measures are not effective, the possibility of the presence of an anomaly should be considered. If a deep opening can be detected, x-ray examination following injection with lipiodol may reveal the existence of a urachal sinus.

On rare occasions, the discharge will be acid in reaction, as shown by the litmus paper test. This justifies a diagnosis of *aberrant gastric mucosa.* The umbilicus, if excised, then will, in fact, reveal a tiny stomach with well-developed mucosa.

Neoplasms. Primary squamous cell carcinoma has been observed at the umbilicus and presents the characteristics of the disease in general. Benign tumors are usually associated with anomalies, as already discussed.

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32

THE PERITONEAL CAVITY

The peritoneum is the lining of the abdominal cavity. The visceral peritoneum covers the liver, intestines, and other organs, whereas the parietal peritoneum covers the interior of the abdominal wall. The peritoneal cavity is the potential space between these two layers; under abnormal circumstances it may be distended with fluid (ascites) or gas (pneumoperitoneum). The lesser peritoneal space is a small potential cavity (lesser omental sac) which lies behind the stomach and lesser omentum and normally communicates with the main peritoneal cavity by the foramen of Winslow. There are numerous compartments which become important in the presence of abscesses and other types of disease (Fig. 1). There are numerous spaces, such as the suprahepatic, infrahepatic, supracolic, infracolic, and pelvic.

PHYSIOLOGY OF THE PERITONEUM

The peritoneum is smooth and lubricated with a small amount of fluid, thereby allowing free motion of the intestines in their peristaltic function. The surface of the peritoneum is covered with endothelium. Beneath this, in the deeper layers of the peritoneum, is an unusually rich network of potential blood vessels which probably function only in times of stress (e.g., inflammation). Lymphatic spaces are likewise abundant. Under normal circumstances hypotonic and isotonic fluids, and even microscopical foreign bodies, are absorbed by means of the capillaries of the portal system and the lymphatics, chiefly the former. Which of the two networks is the more important in the protection mechanism cannot be established.

The peritoneum is highly resistant to infection, and bacteria coming in contact with it by operative contamination and so forth are rapidly destroyed. Phagocytosis by polymorphonuclear leukocytes is apparently the most important factor in this defense mechanism, as shown by the studies of Coller and Brinkman (1) and others. This resistance is so pronounced that historically it actually served as a stumbling block to the acceptance of Lister's teachings, e.g., Lawson Tait and others used the argument that abdominal operations were seldom followed by peritonitis, even though no attention was paid to Lister's principles. We now know that this is true because the resistance of the peritoneum is so much greater than that of other tissues that contamination during an abdominal operation may be severe enough to result in a serious wound infection, yet inflict no demonstrable harm within the peritoneal cavity. It must not be supposed from this statement that peritonitis is not feared; actually it is a most serious infection, because once it gets a foothold the mortality is high. Peritonitis occurs either because of continued contamination from a perforation or because an especially virulent organism is involved. Virulence may be lessened by an increase in the local immunity of the peritoneum. Immunity of the peritoneum to infection may be augmented appreciably by repeated or continued exposures of a mild character. This is exemplified clinically by the decreased tendency for peri-

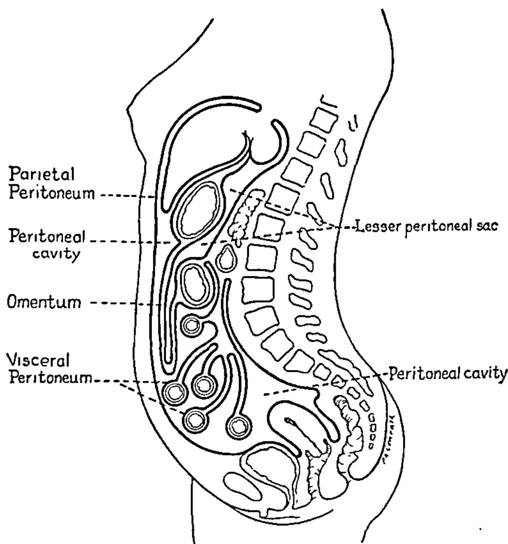


Fig. 1. Longitudinal section of the abdominal cavity in the anteroposterior direction to show the gross structures, and the relation of the visceral to the parietal peritoneum.

tonitis to develop even following serious operations upon the large bowel when there has been an antecedent colostomy or some other operation upon the intestine. As will be discussed in detail later, the healing power of the peritoneum may be augmented greatly by intestinal decompression with no oral intake except a small quantity of water to keep the tube open. Conversely, anything which will tend to increase intestinal movements (e.g., food, cathartics, or prostigmine) will interfere with the normal protective mechanism of the peritoneal cavity against infection.

The omentum, suspended from the greater curvature of the stomach and transverse colon, has often been spoken of as the "wandering policeman" of the abdomen because of its ability to locate and envelop foci of infection and prevent their spread. The omentum therefore plays a major part in the *defense mechanism* in the peritoneal cavity. It may even completely surround a perforation of the intestine and confine the process to a local area, thereby preventing a diffuse peritonitis.

Because of the peculiarities in the sensitivity of the peritoneum to painful and other stimuli, considerable confusion may be experienced clinically in localizing the source of the disease responsible for symptoms. The parietal peritoneum is sensitive to pain, but the visceral peritoneum is sensitive only to certain types of stimuli.

For example, pulling or tugging upon the mesentery of the intestine is painful, although the intestine itself may be cut completely

across with a knife or cautery without the production of any pain. Increased tension in hollow organs may likewise produce pain. The early work of Ross (1888) and Mackenzie (1920) demonstrated that visceral pain of this type is often referred to corresponding skin fields. This pain is frequently localized to areas not overlying the lesion producing the pain, because the localizing quality of the central sensory mechanism with which the visceral (autonomic) fibers make contact is poorly developed in comparison with localization by somatic nerve cells.

The mechanism of the production of the involuntary muscle spasm which appears early over an area of peritonitis is vaguely understood, but it is known to be an important protective mechanism. It may also be explained as a reflex phenomenon arising from the inflamed peritoneum by way of the spinal cord (see Fig. 13 in Chapter 27).

DIAGNOSTIC METHODS

The diagnosis of diseases of the peritoneum and peritoneal cavity is usually difficult and requires a good history and careful methods of examination. Besides inspection, palpation, percussion, and so forth, which are discussed later, certain technical methods may be of great value. For example, if there is ascites, aspiration of the peritoneal cavity will yield fluid. If the fluid is caused by metastases to the peritoneum, it may be blood tinged and when centrifuged, the sediment will show malignant cells. A flat x-ray film is sometimes of diagnostic value. Induced pneumoperitoneum has been advised as a preliminary to x-ray study but is not used widely. A special method of examination has been devised with an instrument called the peritoneoscope, which permits, under certain conditions, direct visualization of parts of the peritoneal cavity. On the other hand, most surgeons prefer a small exploratory incision under local anesthesia for such a diagnostic purpose because it often yields more information and has the advantage of permitting a safe biopsy of suspicious tissue. Under most conditions, however, the surgeon must rely upon the bedside examination of the patient's abdomen.

Experience is, of course, a very important factor in determining the amount of knowledge gained from the bedside examination, in the conduct of which certain habits or routines will be very helpful. Accuracy will be improved if the examiner will always conduct his examination from the same side, e.g., the right, if he is right-handed. Because this procedure of examining the abdomen is so important and requires such expert technic, a few of its essential details will be described.

Inspection. A great deal of information can be obtained by carefully inspecting the abdomen with the patient lying comfortably on his back, under good illumination. If the patient's neck is flexed slightly and the thighs flexed with the knees on a pillow, relaxation will be obtained and the abdominal examination be facilitated. The examiner must also be in a comfortable position in order to obtain the most information. Exposure not only of the abdomen but of the entire torso is necessary for completeness. First the examiner notes the degree of *distention.* Because of normal variations in the contour of the abdomen this may be difficult, although an estimate can be made from the patient's physique. A more accurate method would be to inquire from the patient whether any enlargement has occurred. Enlargement, when present, may be due either to tumor, to the accumulation of fluid in the peritoneal cavity, or to the accumulation of gas and fluid in the intestinal lumen. The examiner looks for *abdominal respiratory movements,* which are normally present, but disappear with the onset of any significant inflammation of the peritoneum. Asking the patient to breathe deeply will make the lag more notable. The patient is asked to cough, which may produce localized pain from peritoneal irritation. Other information may be obtained by noting any *asymmetry* in the abdomen. This may be due to the presence of an abdominal mass, to dilated bowel, herniations, and so forth. Intestinal patterns may be seen with or without peristaltic waves; the significance of these signs in intestinal obstruction has been discussed elsewhere. Discoloration of the skin and various types of skin lesions are of obvious importance and should be scrutinized

carefully, but they usually indicate nonsurgical disease.

Palpation. Palpation of the abdomen, particularly in patients with suspected acute peritoneal inflammation requires the utmost gentleness, yet meticulous thoroughness. It is an art which requires well-developed technic and complete cooperation of the patient. A number of important details may be suggested. Palpation must start from the part of the abdomen not involved so that the painful site will be approached gently without immediately producing pain. However, detection of pain by pressure, a sign which is called tenderness, is an important part of the examination. The patient should be so told, but assured that such pressure-provoked pain will be stopped immediately it is detected. It is important to start the examination with the entire flat surface of the hand in contact with the abdomen, later using the tips of the fingers for eliciting finer details. The main objectives of palpation in diseases of the peritoneum are the detection of (*a*) tenderness, (*b*) various degrees of muscle spasm, (*c*) masses, and (*d*) hyperesthesia of the skin. Tenderness and muscle spasm are often associated in most inflammatory lesions of the peritoneum and will be discussed together. The examiner must be confident, however, that these two signs are actually present and not due to fear or apprehension on the part of the patient. A rough examination may yield false evidence of tenderness and produce *voluntary* muscle spasm, which may lead to an erroneous diagnosis. Muscle spasm, to be of value, must be truly *involuntary*. It exists in various degrees, the least severe of which goes by the name of muscle guard or resistance, which is present in mild or early peritonitis. In the typical case, the muscles contract promptly under moderate pressure of the examining fingers. More severe degrees of muscle spasm go by the name of muscular rigidity, which in the most pronounced cases gives a sensation of boardlike hardness to the abdominal wall, even with the slightest palpatory pressure. Tenderness over the lower margin of the liver can sometimes be detected by having the patient take several deep breaths which results in downward movement of the liver against the examiner's fingers. *Rebound tenderness* is elicited by suddenly releasing the hand exerting the pressure, whereupon the patient complains of acute pain. It has no specific value except that it is sometimes present when direct tenderness is absent and may be an indication of early inflammation. Occasionally, pressure in the left lower quadrant may elicit pain in the right lower quadrant in patients with acute appendicitis (*Rovsing sign*). *Hyperesthesia of the skin* may sometimes be detected in the absence of other signs and will therefore be of value. For example, hyperesthesia is usually present in the right lower quadrant in acute appendicitis; frequently a similar area is found in the left hypochondrium in pancreatitis, and posteriorly behind the gallbladder in cholecystitis.

Palpation is also of value in detecting abdominal tumors. In examining for the existence of a mass, difficulty may arise in that a resistance is felt rather than a definite mass, particularly over inflammatory lesions. Nevertheless, an attempt should be made to locate the mass as exactly as possible, including all of its various characteristics, particularly size, shape, consistency, surface attachments, tenderness, and fluctuation. The examiner must bear in mind all of the possible causes and types of tumors but at the same time realize that the most common tumefaction in the lower abdomen is a distended bladder, particularly in patients with spinal cord disease, skeletal trauma, prostatic obstruction, and following many abdominal operations. The second most common tumefaction in the female is a pregnant uterus. Too often physicians have erroneously mistaken these two enlargements for cysts, neoplasms, or other abnormal masses.

During palpation it may be of some value to have the patient lift his head in order to detect a bulge at the site of a hernia, or to differentiate between abdominal wall and intraabdominal tenderness. Masses in the abdominal wall may also be detected more accurately by this procedure. With the patient lying prone (face down), abdominal palpation may detect differences in tenderness on the two sides which will be very helpful in locating the site of the peritoneal irritation, particularly when there is a question of acute appendicitis. No abdominal examination is

complete without examination of the back with the patient sitting up or lying on his side.

Percussion. Percussion has much less value than inspection and palpation, but should differentiate, as causes of abdominal enlargement, fluid or solid tissue which gives a flat percussion note in contrast to gas in the intestine, which yields a tympanitic note. However, such differences are often deceptive, but a flat x-ray film in these cases may be decisive. Detection of ascites by the demonstration of a fluid wave and shifting dullness is sometimes valuable, but often equivocal. However, dullness to percussion just over the symphysis is practically always present when a lower abdominal tumefaction is due to a distended bladder.

Auscultation. The use of a stethoscope over the abdominal cavity may yield valuable information. The presence of many sounds, such as gurgling and various metallic notes, is usually produced by active peristalsis, and this suggests that the abdominal distention is due to intestinal obstruction rather than to paralytic ileus, which is usually associated with a "silent" abdomen. The appearance or disappearance of abdominal sounds will likewise be of value in indicating changes in the progress of the intraabdominal lesion. For example, disappearance of peristaltic sounds while the patient is being observed is very suggestive of perforation into the peritoneal cavity.

Rectal and Vaginal Examination. No examination of an abdomen for the diagnosis of peritoneal disease can be complete without a *rectal examination* and, when possible in the female, a *vaginal examination.* This is particularly important in acute inflammatory lesions because it will often reveal a difference in tenderness on the two sides, which will aid greatly in the differential diagnosis. In women, an inflamed adnexa can be detected accurately upon vaginal examination by tenderness and induration of this region; if appendicitis is the cause of the inflammation, the adnexal region will be negative and the tenderness usually located higher up on the right side. Inspection of the cervix with a vaginal speculum may yield additional and important information; this is also true of proctoscopic examination.

ETIOLOGIC FACTORS IN PERITONITIS

Any inflammation of the peritoneum, whether caused by infection, trauma, or chemicals, may be classified as a peritonitis, but only that of bacterial origin is of much significance clinically, especially since the nonbacterial types heal so readily. If infection is spread diffusely throughout the peritoneal cavity, it is spoken of as general peritonitis in contrast to local peritonitis. It responds fairly well to antibiotics if there is no persistent source. If the source persists, as in a perforated appendicitis or perforated ulcer, antibiotics are of little avail; without *surgical treatment such lesions* are usually fatal. Even though general peritonitis responds favorably to antibiotics, local abscesses tend to form.

There are certain groups of organisms which are particularly virulent in the peritoneum, for example, *E. coli,* streptococcus, pneumococcus, tubercle bacillus, gonococcus, and staphylococcus. On many occasions, more than one organism will be present and may be demonstrable by culture. Such a mixed infection may or may not be true symbiosis. Many observers are of the opinion that various strains of gas bacilli are responsible for a great deal of the toxemia accompanying peritonitis caused, for example, by a perforated appendix.

There are numerous etiologic factors which may act in the production of peritonitis. These are described elsewhere in detail but are listed below to emphasize the variety and importance of the mechanisms:

1. *Appendicitis with perforation* is by far the most common cause of peritonitis and accounts for many deaths in the operated as well as nonoperated patients (Fig. 2). Early removal of the appendix lessens considerably the chance of a fatal outcome by eliminating the source of infection.

2. *Perforated peptic ulcer,* either duodenal or gastric, is an important and fairly frequent source of peritonitis, but the mechanism is quite different from that produced by a perforated appendix. Since the contents of the stomach and duodenum are practically sterile, the immediate bacterial contamination is usually insignificant. The gastric and duodenal contents are so damaging to the peri-

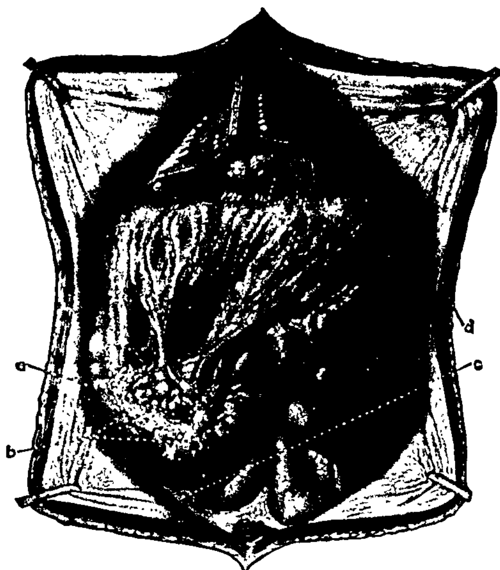


Fig. 2. Autopsy appearance of diffuse purulent peritonitis arising from a perforated (and therefore neglected) appendicitis. a, omentum adherent to appendix and adjacent coils of intestine; b, yellowish green protective plastic exudate; c, pus between coils of intestine; d, cloudy fluid found at a distance from the appendix. (From Babcock. Textbook of Surgery, W. B. Saunders.)

toneum, however, that even slight contamination (unless immediate repair is done) is sufficient to result in a serious bacterial peritonitis in 48 to 72 hours.

3. *Gonorrheal salpingitis* is a frequent source of peritonitis because of leakage of pus from the Fallopian tube, but the resultant infection usually remains localized and rarely produces the serious manifestations seen in appendiceal peritonitis.

4. *Peritonitis due to trauma* (caused by perforation of intestine, bladder, and so forth) is of special importance because of the difficulty in diagnosis created by the simultaneous presence of other injuries. Perforation of the intestine allows the direct contamination of the peritoneal cavity by fecal material including bacteria. The mechanism of the production of peritonitis due to contamination of urine is dependent upon chemical irritation with secondary infection.

5. *Peritonitis following celiotomy* is unfortunately an occasional complication of abdominal operations, much to be feared but usually avoidable. Among the factors producing peritonitis of this type should be mentioned: (*a*) leakage of an intestinal suture line, (*b*) contamination during operation, i.e., faulty technic, including particularly *virulent streptococci from the nose and throat*

of the operating room personnel, and (c) leakage of bile (bile peritonitis, see below).

6. *"Idiopathic" primary peritonitis* is a term frequently used to denote the fact that the pathogenesis of the peritonitis is obscure, although apparently blood-borne from a primary focus elsewhere. Streptococcus and pneumococcus peritonitis are types of peritoneal infection comprising this group.

7. *Tuberculosis* occasionally invades the peritoneal cavity but is usually secondary to an active lesion in the lungs, mesenteric lymph nodes, Fallopian tubes, and so forth.

8. There are numerous *miscellaneous lesions* capable of producing peritonitis which, when considered singly, are not of considerable importance because of their rarity. Diverticulitis with perforation (most commonly of the sigmoid) may produce a serious and fatal peritonitis unless operative repair or fecal diversion is performed soon after perforation. Meckel's diverticulitis may also give rise to peritonitis because of perforation through the wall of the diverticulum. Perforation of a typhoid ulcer of the ileum, and peritonitis secondary to puerperal sepsis were common several decades ago, but during recent years have practically disappeared.

A gallbladder may perforate because of acute cholecystitis, and the resultant leakage of bile into the peritoneal cavity may produce a serious type of peritonitis. Rarely, leakage of bile through traumatic rupture of the common duct, ulceration of the duct, and so forth, may result in *bile peritonitis*. The irritative action of bile on the peritoneum results in exudation of huge quantities of plasmalike fluid, frequently resulting in shock. The local protective properties are reduced, resulting occasionally in a severe inflammatory peritonitis, which usually becomes infected secondarily. Therefore, the seriousness of bile peritonitis is not related primarily to the bile itself but to the irritative quality of the bile, which may produce profound chemical alterations in the body or give rise to secondary infection in the inflamed area. The gangrenous tissue associated with a perforated gallbladder will no doubt also be an important factor in the development of infection and perhaps also in absorption of toxin from the necrotic tissue.

PERITONITIS DUE TO PERFORATION OF A VISCUS

Of the various types of peritonitis just enumerated, there are several whose pathology, manifestations, and treatment are similar. In this group should be mentioned appendicitis with perforation, perforated peptic ulcer, traumatic perforation of intestine, and postoperative peritonitis (Fig. 3). The predominating organism in peritonitis caused by such lesions is *E. coli,* with the streptococcus, staphyloccus, and proteus organisms occurring less commonly.

Pathology. The first evidence of peritonitis is a hyperemia and redness of the visceral as well as parietal peritoneum, which gradually loses its luster and assumes a grayish color. A clear fluid soon accumulates, but this exudate rapidly becomes cloudy and contains fibrin. On some occasions, fibrin appears to be deposited without the accumulation of free fluid. Within two or three days the fluid thickens and becomes true pus. In the meantime the fibrin and omentum attempt to mat various loops of intestine together so that the infection will remain localized and not be diffused everywhere throughout the peritoneal cavity. The success or failure of sealing of the perforated intestine or local lesion, with the development of a local abscess is dependent upon the rapidity of leakage and, to a less extent, upon the resistance of the patient and virulence of the organisms. If the leakage is slow, adhesions may form rapidly enough to form a local abscess and prevent diffusion of the intestinal contents of the various parts of the peritoneal cavity. Most of the fibrin is absorbed as the process heals, but if the damage has been great, permanent adhesions may result. The pathologic processes, such as local abscess, adhesions, and so forth, are discussed in more detail under Complications. In addition to the changes mentioned, if the peritonitis is diffuse, the entire bowel may become distended, paralyzed, and filled with gas and fluid, a condition known as *paralytic ileus* (see p. 823). The systemic effects of inflammation in general are usually pronounced. Because of vomiting and failure of absorption of fluid from the damaged intestine, marked dehydration may also be present. In general, there are cer-

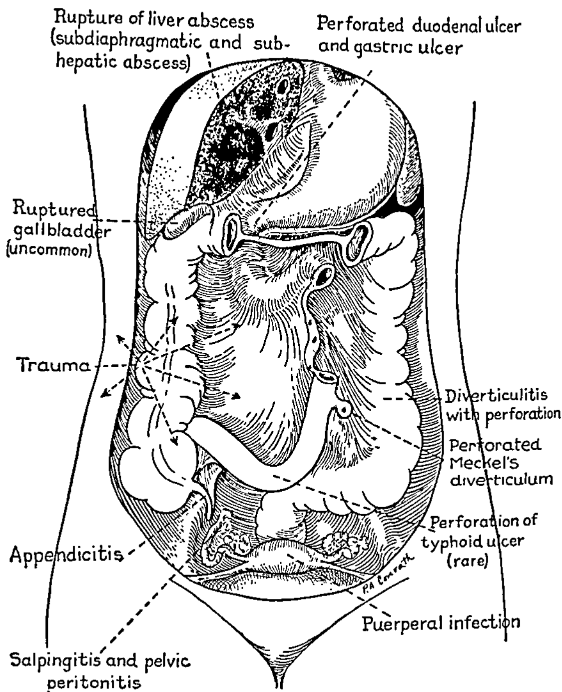


Fig. 3. Schematic drawing to illustrate the numerous lesions which may give rise to local or general peritonitis

tain pathways by way of which infective fluid from perforative lesions may spread to other parts of the peritoneal cavity. For example, purulent exudate produced by a perforated appendix may reach the subphrenic space by way of the right external paracolic groove. Fluid escaping from a perforated peptic ulcer may spread from the right subhepatic space by overflowing anteriorly across the colon into the right infracolic space, thence into the pelvis or across the ascending colon to the right external paracolic groove.

Clinical Manifestations. The clinical manifestations will depend largely on the stage of disease and the location, nature, and severity of the primary or causative lesion. The manifestations produced by the causative lesion itself should, if possible, be distinguished from those of peritonitis; they are usually elicited by a careful history. The term "peri-

toneal irritation" is used to describe an early inflammatory lesion which frequently precedes actual peritonitis. Obviously, any diffuse peritonitis starts as a local process, but the term "local peritonitis" implies the confinement of the infection to a local area by such barriers as omentum, adhesions, and adjacent organs. Whether a local or general infection is present will therefore depend not only on the lapse of time but also on the resistance of the patient.

LOCAL PERITONITIS. Pain is the first complaint and is usually so severe as to confine the patient to bed. Local tenderness is demonstrable early and is located over the lesion, in contrast to the referred pain which may be experienced during the onset. Anorexia and nausea are almost always present, but vomiting is variable. Muscle spasm is constant over the lesion, but is not present over the entire abdomen. Tachycardia occurs early, but fever is seldom encountered for 18 to 24 hours. After a few days, the above symptoms lessen in severity and, as the muscle spasm decreases, the local abscess may be palpable through the abdominal wall as a definite mass. Leukocytosis is rarely absent as long as pus remains undrained.

It is extremely important to discriminate between a true rigidity of the muscles of the anterior abdominal wall and voluntary muscle spasm which may be incited by rough palpation, cold examining hands, and so forth. True muscle rigidity, which is so pathognomonic of peritoneal irritation is of involuntary origin, may be elicited constantly and cannot be eliminated by distracting the patient. When examining a patient for muscle spasm and local tenderness, the examiner must assume a reassuring attitude and be gentle during the examination. If pain is inflicted, voluntary muscle spasm is incited and the information gained may be inaccurate. For this reason, it is usually wise not to palpate the area complained of until the rest of the abdomen has been examined.

DIFFUSE (GENERAL) PERITONITIS. Diffuse pain is one of the first symptoms to appear but is usually secondary to the primary lesion as is exemplified by the severe pain and prostration produced by a perforated peptic ulcer. On the other hand, there is little pain associated with peritonitis produced by a leaking suture line, except that produced by distention. A few hours after the onset of the diffuse infection, anorexia and nausea appear and are soon followed by vomiting. Localized muscle spasm, preceded by diffuse tenderness, is manifested early and after several hours may be sufficient to present a boardlike sensation to palpation. Usually, however, the muscle spasm and tenderness, while diffuse, are more marked over the site of the perforation. Leukocytosis (10,000 to 30,000) is manifested early and usually persists. Tachycardia develops early, but fever is encountered only after 18 to 24 hours. The pulse gradually becomes weak and poorly sustained, and is one of the most reliable means of estimating the severity of the infection and the physical condition of the patient relative to operability and prognosis. Distention (Fig. 4) due to paralysis of the intestine (paralytic ileus) may appear within 24 hours, but rarely becomes pronounced for two or three days. This cessation of peristalsis, obviously resulting in constipation, is one of Nature's methods of preventing the spread of the infection. The dullness of free fluid may be demonstrable in the flanks. As noted previously, the clear fluid which forms first *rapidly turns to pus, which at operation is ob*served to have a characteristically foul fecal odor if the infection is caused by *E. coli*, as is usually the case.

After a time the pain becomes less noticeable, but the vomiting (more often slight regurgitation) persists regardless of whether or not food or water is taken by mouth. Occasionally, the vomitus is fecal, indicative of regurgitation from paralyzed ileum. Restlessness is pronounced and unless adequate sedation is given, the patient will suffer physically from lack of sleep. After two or three days all the classical signs of peritonitis will be demonstrable. The Hippocratic facies, consisting of anxious expression, sunken and staring eyes, pinched nose, and dusky pallor is pathognomonic of a diffuse peritonitis, but is of little value therapeutically, since it is a late manifestation. The patient retains consciousness until a short time before death. Since the introduction of intestinal decompression, parenteral fluids, and chemotherapy in the treatment of peritonitis, many of the cardinal manifestations mentioned above are



Fig. 4. Distention is one of the most constant of the signs of peritonitis, but is slow in forming, usuall requiring two or three days for its maximum development. Part of the swelling is due to accumulatio of exudate but most of it is due to paralytic ileus which is produced by the peritoneal infection.

rarely seen. Under this therapy as described in detail later, the patient may pass safely through the peritonitis phase of the infection, but later may develop abscesses which usually require drainage (Fig. 5).

Postoperative peritonitis produces manifestations which may be much more insidious. The abdominal pain, tenderness, and muscle spasm are much less pronounced. Moreover, the pain produced by the peritonitis is apt to be mistaken for the abdominal discomfort incident to laparotomy. Vomiting and distention are quite constant. Frequently, tachycardia with a gradually weakening pulse, fever, distention, and occasional vomiting are the only demonstrable manifestations, but the diagnosis should not be difficult, especially if other complications (such as wound infection or pneumonia) capable of producing a similar clinical picture are excluded.

The severity of symptoms is dependent upon many factors, among which should be mentioned etiology, virulence of the organism, age of the patient, and type of treatment. In children, peritonitis develops rapidly, usually presenting all of the classical symptoms and signs, whereas in the aged, progression of the infection may be slow and atypical which is also true of postoperative peritonitis. For example, pain, muscle spasm, and even fever may be insignificant or absent. In the aged, even though few manifestations are exhibited, the prognosis is nevertheless poor and in fact worse than in children.

Differential Diagnosis. In no other group of disease is it so necessary to make an early accurate diagnosis as it is in the diseases leading to peritonitis, because early operation is often essential to the prevention of a fatal outcome. The number of diseases capable of simulating or producing peritonitis are innumerable and, at times, offer serious diagnostic difficulty. In reality, it is not necessary to establish accurately the cause of the peritoneal manifestations, but it is absolutely essential to make the correct decision as to whether or not an operation should be performed, since an error in this decision is serious and may lead to a fatality. In a consideration of differential diagnosis of the types of peritonitis it may therefore add to clarity to classify those diseases, which are discussed in detail later, into three groups: 1. diseases producing peritonitis for which operation is imperative; 2. diseases not associated with peritonitis, but for which operation is imperative or advisable; and 3. diseases not producing peritonitis and for which operation is contraindicated.

1. *Diseases Producing Peritonitis and for which Operation Is Imperative.* A patient with a general peritonitis caused by a *perforated appendix* may present such diffuse tenderness and muscle rigidity that the source of the infection will be undetermined. The diagnosis can perhaps best be made by careful consideration of the history, supported by the fact that the maximum tenderness and

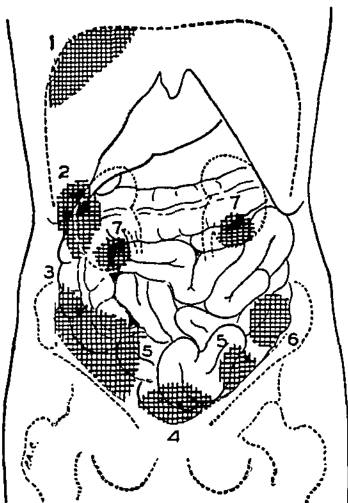


Fig. 5. Common sites for the location of intra-abdominal abscesses. 1, above and behind the liver (subdiaphragmatic), commonly secondary to suppurative appendicitis. 2, inferior surface of the liver (subhepatic) may follow suppurative appendicitis or acute cholecystitis with rupture of the gallbladder. 3, right lower quadrant, the common site for an abscess following suppurative appendicitis. 4, pelvis, may be secondary to appendicitis or acute pelvic inflammatory disease 5, tubo-ovarian region, secondary to salpingitis. 6, region of the sigmoid, secondary to ruptured diverticulitis. 7, about the lower pole of the kidneys (perinephric abscess).

muscle spasm will be located over the right lower quadrant. While the appendix is unperforated, the pain is not diffuse but usually located in the right lower quadrant. If the peritonitis is caused by a *perforation of a peptic ulcer* the point of maximum tenderness is more apt to be in the upper abdomen, but of more importance is the fact that the onset of pain, which is confined to the epigastrium, at least for a few hours, will be sudden and be of much greater severity than that produced by appendicitis. Moreover, the patient is invariably severely prostrated very soon after the perforation. An x-ray taken with the patient in a sitting posture will almost always reveal a collection of gas under the diaphragm, especially in the right side.

The symptoms of peritonitis caused by perforation of an *inflamed diverticulum* of the sigmoid differs from the other types of peritonitis in that the pain at the onset practically always is confined to the left lower quadrant unless the peritonitis becomes general. Palpation of the abdomen will likewise reveal the tenderness and muscle spasm located to the greater extent at least, in this area. Perforation of a diverticulum occurs more commonly in elderly people than in young adults.

An accurate diagnosis of an ulcerated or perforated *Meckel's diverticulum* may be difficult. About the only diagnostic feature, especially in its differentiation from peritonitis of appendiceal origin, is the location of maximum pain, local tenderness, and muscle spasm, which is usually demonstrable outside the right lower quadrant and frequently in the neighborhood of the umbilicus. Moreover, blood may at times be found in the stool.

Early diagnosis of a perforation of a *typhoid ulcer* may be difficult because of the existence already of considerable abdominal tenderness and pain and because of its rarity today. The perforation may not be accompanied by severe pain and muscle spasm, which are seen in patients with rupture of a peptic ulcer, but the presence of the symptoms and signs of typhoid fever should, of course, prevent confusion with such conditions, the other more common sources of peritonitis requiring operation. *Acute cholecystitis* is ushered in almost invariably with severe pain in the right upper quadrant, radiating frequently to the tip of the scapula and followed by fever, leukocytosis, and tachycardia with or without jaundice. There is local tenderness and muscle spasm. All signs increase sharply if the gallbladder perforates, especially if it occurs free into the peritoneal cavity. Perforation makes operation urgent. In the absence of perforation, surgeons differ as to whether or not operation is indicated for acute cholecystitis.

2. *Diseases Not Producing Peritonitis but for Which Operation Is Imperative or Advisable. Intestinal obstruction* because of distention may be difficult to differentiate from peritonitis, but an accurate consideration of the history, particularly as related to the onset and type of pain, will usually lead to the correct diagnosis. Fever, tachycardia, and leukocytosis are less common in intestinal obstruction. The pain of peritonitis is usually constant and confined to one area, whereas the pain associated with intestinal obstruction is intermittent and inconstant, coming on in cramping attacks, lasting a minute or two, and subsiding for an equal length of time. Visible peristalsis will be demonstrable through the anterior abdominal wall, except in obese patients, and in the late stage when the intestine is paralyzed. Likewise, auscultation will reveal an unusual amount of peristaltic gurgling except in the late cases, in contrast to the silent abdomen of peritonitis. If a loop of gangrenous gut is present (strangulation), the pulse will be rapid and the patient will appear unusually ill considering the duration of his illness. It is important to note that intestinal obstruction is usually secondary to a pre-existing lesion, such as hernia (strangulated hernia), tumor (e.g., carcinoma of the colon), and adhesions (produced by operation or inflammation). In infants and young children, especially the former, *intussusception* is commonly observed and will present many of the manifestations of peritonitis, including vomiting and prostration. However, fever is not present; mild abdominal tenderness is noted in contrast to the acute tenderness and muscle spasm which accompanies peritonitis. A mass in the region of the ascending, transverse, or descending colon is practically always demonstrable. If the intussusception has been present for many hours there is practically always a history of bloody diarrheal stools, or the passage of pure blood.

Acute mesenteric thrombosis is a rather uncommon condition frequently associated with, but not responsible for, peritoneal suppuration except, perhaps, in the terminal stage of the disease. It may occur in supposedly healthy persons without antecedent peritoneal symptoms or obvious disease. The onset is dramatic, with intense pain, and is associated within a few hours with the major manifestations of shock. If the colon is involved, the shock will be more intense than when the small intestine is affected. Examination will sometimes reveal a tender tubular mass which represents the loop of intestine, the vessels to which are thrombosed. A mild bloody diarrhea is not uncommon. Regardless of the presence or absence of diarrhea, blood-stained fecal matter will usually be found in the rectum. Muscle spasm is usually not so pronounced as it is in peritonitis with equally toxic manifestations. On many occasions, the intestine attached to the mesentery containing the involved vessels will become gangrenous, thereby making resection imperative. On the other hand, gangrene may not be produced by the thrombotic process; in that event, the

condition should obviously be classified in group 3, below.

3. *Diseases Not Producing Peritonitis and for Which Operation Is Contraindicated.* *Acute pancreatitis* is associated constantly with severe pain in the epigastrium and frequently with nausea and vomiting. Muscle spasm in the upper abdomen is fairly constant. Leukocytosis is usually present. The amylase content of the blood and urine is almost always elevated early in the disease, but this elevation may not persist longer than 12 to 18 hours. In acute pancreatic necrosis (much less common than acute interstitial pancreatitis) shock may develop with a rapid, weak pulse. If the diagnosis can be made, operation is contraindicated, but often indeed lesions (e.g., perforated ulcer) requiring emergency operation cannot be excluded.

Pyelitis is frequently confused with lesions (e.g., appendicitis) producing peritonitis, thereby leading to the performance of a needless laparotomy. Pyelitis occurs in patients of any age, but in children is most often confused with lesions demanding laparotomy. The disease is much more common in girls than in boys and may be ushered in insidiously with pain on one side of the abdomen, associated with abdominal tenderness, mild muscle rigidity, nausea, and vomiting. Chills are not uncommon. Careful examination will rarely fail to reveal the fact that the most tender area is located posteriorly over the kidney. The presence of pus cells in the urine should lead one to the correct diagnosis of pyelitis. Obviously, if the left kidney is affected, localization of the pain over the left side of the abdomen should help eliminate acute appendicitis in the differential diagnosis.

Acute enteritis due to "food poisoning," i.e., caused by organisms of the colon and proteus groups, may offer considerable diagnostic difficulty because of the presence of nausea, vomiting, and abdominal pain. The pain and tenderness, however, are usually poorly localized and are inclined to shift from one area to another. Moreover, nausea and vomiting are apt to precede pain, in contrast to the sequence in lesions leading to peritonitis. Muscle spasm of consequential degree is likewise rarely present. Leukocytosis usually does not occur. Frequently, a diarrhea is present, thereby issuing a warning that the diagnosis of early peritonitis must be quite definite before laparotomy is performed.

Acute salpingitis is frequently confused with lesions (particularly appendicitis) for which laparotomy is indicated. If the tenderness and pain are limited to the left side there will, of course, be no confusion with appendicitis. The history of frequency and burning on urination (urethritis), vaginal discharge, and positive findings on vaginal examination should lead to the correct diagnosis of salpingitis. In this disease, the severe manifestations of toxemia characteristic of peritonitis caused by *E. coli* are absent. Peritonitis, limited usually to the pelvis, frequently results from acute gonococcal salpingitis and, in that respect, does not fit literally into this group, but operation is distinctly contraindicated regardless of whether or not the infection extends beyond the pelvis.

In children, *acute mesenteric lymphadenitis* is rather commonly observed and usually presents a clinical picture which is differentiated from early peritonitis with extreme difficulty. Abdominal tenderness, pain, nausea, vomiting, leukocytosis, and even other signs of peritonitis may be present and develop acutely. About the only evidence which can be used to eliminate the diagnosis of peritonitis is found in the type of tenderness and pain. The pain and tenderness will usually not be localized to the right lower quadrant as it is in the most common disease (appendicitis) to be eliminated in differential diagnosis. The muscle spasm is apt to be diffuse and likewise located outside the limits of the anatomic location of the appendix.

There is still another group of patients, including both children and adults, which offers serious difficulties in differentiation from peritonitis; this syndrome consists of abdominal pain and mild muscle spasm, which is presumably a *peritoneal irritation secondary to upper respiratory infections*. Anorexia and nausea are common, but vomiting is rare. Leukocytosis is usually absent. The presence of fever is variable, though usually present, and tends to support the decision to refrain from a laparotomy, especially if the manifestations are suggestive of a localized peritonitis and not a general peritonitis. The performance of a laparotomy in these individuals

may, of course, be detrimental and damaging, and should be avoided if the diseases for which laparotomy is imperative can be reasonably excluded.

Ulcerative colitis (*"idiopathic" or amebic colitis*) may offer more difficulty in differentiation from the lesions necessitating operation. In the former instance there is practically always a history of pre-existing abdominal tenderness and pain. Vomiting is rarely present. Amebic dysentery of the acute type simulating peritonitis is usually accompanied by fever, diarrhea, and blood in the stool. Differential diagnosis is extremely important in amebic dysentery, since the erroneous performance of a laparotomy in this disease is very deleterious and often fatal. The pain in *spastic colitis* is usually mild and rarely localized. Nausea, vomiting, and leukocytosis are rarely present.

There are a few *miscellaneous diseases* which, on rare occasions, may produce pain and other peritoneal manifestations in the abdomen. Of this group, angina pectoris and pneumonia should be mentioned particularly. Although the pain of coronary thrombosis and occlusion (angina pectoris) may occasionally be referred to the epigastrium and be accompanied by muscle spasm, it will rarely be difficult to differentiate the disease from peritonitis, because of the history of pain in the left side of the chest and left arm, and the relative infrequency of vomiting and leukocytosis. It must be remembered, however, that vomiting may be present in acute coronary occlusion. When *pneumonia* occurs in a lower lobe there occasionally is sufficient diaphragmatic pleurisy to produce pain, tenderness, and muscle rigidity of referred character in the upper part of the abdomen. The presence of pulmonary signs, such as increased respiratory rate, respiratory grunt, sharp limitation of abdominal signs to the upper abdomen, will rarely fail to differentiate the disease from a peritonitis. Occasionally *acute nephritis*, particularly if bilateral, will present generalized pain, tenderness, and muscle rigidity over the abdomen, simulating peritonitis. Urinary findings should lead one to the correct diagnosis. The importance of establishing a correct diagnosis can be appreciated when one considers the fact that a laparotomy performed in any of the three diseases mentioned above (pneumonia, coronary occlusion, and acute nephritis) is apt to lead to a fatal outcome.

Treatment. Prophylactic therapy in reality is most important insofar as peritonitis is secondary to other lesions or to contamination which, if prevented or treated promptly, will eliminate infection of the peritoneal cavity. For example, when dealing with acute appendicitis, appendectomy should be done as soon as possible after the diagnosis is made, hoping to remove the diseased appendix before it perforates and contaminates the peritoneal cavity. Likewise, closure of a perforation of an intestine should be done as early as possible after injury, since the possibility of the development of a general peritonitis is dependent for the most part upon the length of time intervening between the injury and operative repair. The care with which the tissues are handled during the operation is also important. Rough handling may encourage the development of infection or even result in a tear or puncture of a loop of intestine, an accident which might lead to a fatal peritonitis unless repair is instituted.

Once a peritonitis is present, the question of operation is dependent almost entirely upon: 1. the source of the infection; and 2. the condition of the patient. Years ago, opinions differed as to whether or not immediate appendectomy should be performed in advanced peritonitis resulting from a *perforated appendix;* some surgeons considered it safer to treat the patient conservatively for a time. However, since the advent of penicillin and other antibiotics, operation can be performed much more safely in the face of a general peritonitis. Since a continuous leak in the peritoneal cavity is dangerous, it can now be said that immediate operation is preferable. About the only warning of danger lies in the axiom that no patient should be operated upon if he is so ill as to make it appear that operation is going to result in a fatality. Under such conditions nonoperative procedures should be instituted which may so improve the general condition as to make operation safer. Operative procedures are designed to remove the source of the infection if possible (e.g., appendectomy), to divert fecal stream, or to drain an abscess at the site of perfora-

tion in order to prevent further contamination from the peritoneal cavity.

To prevent spread of peritonitis the gastrointestinal tract is put at rest by allowing the patient *nothing by mouth,* and by insertion of a nasal tube to obtain Wangensteen drainage. Intestinal decompression alone will reduce the distention markedly, providing the tube is kept open. For the purpose indicated, passage of the tube into the ileum has no advantage over a gastric tube.

Sufficient fluid to correct water and electrolyte deficits must be administered, primarily by the intravenous and subcutaneous route. Glucose may be given by vein in 5 or 10 per cent solution but not faster than 300 to 500 ml. per hour. A 5 per cent solution may be given at a rate of 500 ml. per hour with utilization, and a 10 per cent solution at relatively the same speed with 95 per cent utilization. To prevent protein starvation, amino acids should be added on occasions to the glucose for nutritional purposes. Parenteral vitamins are also indicated. An amount of fluid equivalent to that lost by decompression must be added to the 2,500 or 3,000 ml. designated as the early requirement; half of this should contain physiologic saline because of the salt lost in the decompression fluid. In patients long on a potassium-free intake, potassium chloride (4 grams per liter) will be needed to correct or prevent a potassium deficiency, which is particularly likely following correction of dehydration with saline alone. The restoration of electrolyte balance can be more safely carried out over the course of two or three days than by attempting to correct the deficiency quickly. Clinical observations of the correction of dehydration are the best index for the continued administration of this electrolyte solution. After correction of the initial hypochloremia, the administration of more than 6 or 8 grams of sodium chloride (in addition to that lost by decompression, and the like) per day is very apt to lead to salt edema, especially if hypoproteinemia is severe; in such a case, urine output is small. Transfusions of whole blood or of plasma are nearly always indicated especially to correct hypoproteinemia which follows actual loss of plasma into the peritoneal exudate and wall of the intestine.

Since patients with peritonitis are restless, it is extremely essential that they be given adequate sedation, especially at night, to encourage sleep. It is not sufficient that the patient rest, *he must receive a required amount of sleep daily* if his general resistance is to be maintained. Elevation of the head of the bed one or two notches will add to the comfort of the patient. It is thought by some that elevation of the head of the bed (Fowler's position) prevents absorption from the upper part of the peritoneal cavity and thereby lessens the severity of the disease. However, this has never been proved; moreover, this position is harmful in that it tends to keep the patient immobilized and promotes venous stasis, thus encouraging thrombosis in veins of the leg and thigh.

Enemas may be given, but are seldom of any value. Peristaltic stimulants, such as pitresson and prostigmin, are *contraindicated* because the excessive peristalsis produced by them would tend to spread the infection.

The application of heat by a bake or an electric pad is usually a source of comfort to the patient and is to be preferred to cold applications. Bisgard (2) has shown that the application of heat over the abdomen decreases peristalis whereas cold increases it. This fact may be utilized in the treatment as discussed in the preceding paragraph. When distention is prominent, Fine and associates (3) have reported reduction by having the patient breathe 95 per cent oxygen.

Chemotherapy is of definite value in peritonitis. Although *E. coli* is perhaps the most important organism encountered clinically in peritonitis, it is well known that the infection is often indeed a mixed one; the streptococcus and staphylococcus are commonly found with *E. coli.* If possible, the causative organisms should be isolated and sensitivity tests performed to determine which antibiotics should be given. Although pencillin is slightly active against *E. coli,* Bloemers and Kempf (4) have shown that its effect against that organism has been greatly exaggerated. Those authors found streptomycin much more effective than penicillin. There is evidence that aureomycin, chloromycetin, and terramycin (Long and associates, 5) may be as effective against most gram-negative organisms of the enteric group as is streptomycin. Aureomycin and terramycin can be

given intravenously. Since a pyogenic (gram-positive) organism is often present along with *E. coli,* it is usually desirable to give penicillin along with one of the three agents just mentioned (see also Chap. 5).

For the prevention of peritonitis, chemotherapeutic agents have been recommended for oral use in reducing the bacterial count of the intestinal tract, although not all surgeons believe this procedure exerts a significant role in the reduction of peritonitis. Succinylsulfathiazole, in a dose of about 12 grams per day, and sulfathaladine, in a dose of 6 grams per day, for three or four days before operation is given orally by many surgeons when intestinal resection, particularly of the colon, is contemplated. Streptomycin given in a dose of 0.5 gram by mouth four times per day will eliminate the coliform bacteria from the feces more rapidly than the sulfonamides just mentioned, namely, in 48 hours (6), except that slightly longer may be required in the presence of an ulcerating lesion. Tetracycline (7) and neomycin are also rapidly effective (8), within 48 hours.

An enterostomy in general peritonitis is not only a useless but an unnecessarily deleterious procedure; it rarely relieves distention as long as the bowel is paralyzed, whereas as soon as intestinal movements are regained sufficiently to result in expulsion of gas through the enterostomy opening, it will not be needed. It should be emphasized that the procedure of drainage in operations in peritonitis is often misunderstood; the insertion of drains does not drain the general peritoneal cavity. As shown by Yates (1905), drainage of the peritoneum affects only a local area and not the entire infected surface. Drains should therefore be used only to aid in evacuation of a definite abscess, or in exteriorizing a possible site of contamination or infection (e.g., an insecure anastomosis); they should always be of soft material (e.g., gutta percha) lest the intestine or other organs be injured by constant pressure of the drain. The sump drain used by some surgeons in peritonitis may be effective for a few hours, but beyond that period *cannot possibly* drain any part of the peritoneal cavity other than the local area. It disregards facts established three or more decades ago.

Complications. *A certain percentage of* patients recovering from diffuse peritonitis develop complications of one type or another. Most of the complications are serious, although with good medical care, a lethal outcome can usually be avoided.

1. *Local abscess* may be single or multiple and is formed by the localization of areas of infection by omentum, adhesions, loops of intestines, and so forth. They frequently form at dependent sites, such as the pelvis and the concavities of the peritoneal cavity, *early in the infection before adhesions are* formed. Abscesses also develop between loops of intestine and their mesentery and *under the diaphragm.* The persistence or recurrence of fever after the severe toxic symptoms produced by the peritonitis have subsided is usually the first indication of the presence of an abscess. A mass may or may not be palpable, depending upon the size and location of the abscess. Consistent local tenderness over the abscess is usually present, but muscle spasm is absent in most instances. If the abscess is in the pelvis, rectal and vaginal examination will almost invariably yield positive information as to its presence. Such manifestations as fever, anorexia, failure to gain weight, weakness, and restlessness, usually accompany peritoneal abscess. Occasionally, after a variable length of time, an abscess will rupture into a loop of intestine and in this way discharge its content. This is to be suspected when the local signs suddenly subside, and the fever suddenly drops. Occasionally, the pus will be seen in the feces if looked for, especially in abscesses which have broken into the rectum. *Evacuation by this* means is usually as effective as incision, but unfortunately occurs only after the abscess has been present for many days or weeks. Incision and drainage are usually indicated but may be delayed if definite regression is revealed after a day or two of conservative treatment. Masses which consist primarily of inflamed omentum and adherent loops of bowel regress very satisfactorily following conservative treatment, but true abscesses will require drainage unless they rupture into the bowel. If incision is resorted to, drains should, of course, be left in the wound and, if the cavity is large, should not be removed for four or five days or longer. A Penrose *drain (tube of thin soft rubber),* a rolled strip

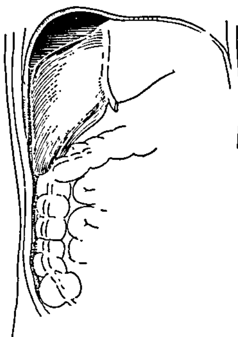


Fig. 6. Pathway of spread of infection into the subdiaphragmatic space with formation of an abscess. Cross-section to how the relationship to other organs. The shaded track along the ascending colon indicates the probable path of the infection in its migration to its present location. This pathway rapidly becomes sealed, however, with adhesions and scar tissue.

of rubber dam, or a cigarette drain (rubber dam around gauze) are drains most often used. In general, abscesses should not be drained across the free peritoneal cavity.

2. *Subdiaphragmatic* (*subphrenic*) *abscess* presents features which are so different from those of other intraperitoneal abscesses that it is considered separately. An abscess may develop under the diaphragm as a complication of almost any infection within the peritoneal cavity. Inflammatory lesions of the liver and biliary passages, stomach or duodenum, and appendix account for about 60 per cent of the cases (Hochberg, 9). At times it is difficult to understand how the infection travels upward above the liver from the numerous sources in the peritoneal cavity (Fig. 6). As would be expected, the majority of abscesses are on the right side. Dividing the right subphrenic space into posterior superior, anterior superior, and anterior inferior, Ochsner and associates (10) found the posterior superior space to be involved in 34 per cent of a large collected series. Next in frequency was the left anterior inferior space (20.5 per cent). Not all subphrenic infection proceeds to suppuration. Details of diagnosis may be found in the splendid article by Hochberg (9).

The existence of a subphrenic abscess should be suspected when the fever (produced by the initial lesion), which may have subsided somewhat, becomes more elevated and irregular. Systemic symptoms such as anorexia, weakness, sweating, malaise, nausea, and occasionally vomiting may be present. Pain is insignificant and is rarely of any aid in the localization of the abscess which is presumed to exist. However, palpation may reveal slight tenderness over the twelfth rib posteriorly, or along the costal margin anteriorly (depending on the location of the abscess). It may therefore be of some aid in determining the location of the abscess; otherwise abdominal examination is usually negative. The leukocyte count is usually markedly elevated. When a subdiaphragmatic abscess is suspected, the limits of hepatic dullness should be observed closely by percussion from day to day. However, the x-ray is of greater value and will be more accurate in determining the degree of elevation of the diaphragm. This observation is important since a subdiaphragmatic abscess rarely occurs without an elevation of the diaphragm on the affected side (Fig. 7). However, ele-

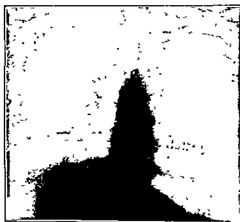


Fig. 7. Roentgenogram revealing elevated diaphragm (right) caused by subdiaphragmatic abscess resulting from perforated appendicitis. By far the majority of subdiaphragmatic abscesses occur on the right side.

Fig. 8. Anteroposterior and lateral view of subdiaphragmatic abscess containing gas. The right diaphragm is markedly elevated. Gas formation is unusual, but is pathognomonic of subdiaphragmatic abscess when found. Patient had a gastric resection performed several weeks prior to the time these x-rays were taken.

vation of the diaphragm is by no means pathognomonic of subphrenic abscess, since it may be elevated by numerous lesions in the absence of pus. Absence of respiratory excursions of the diaphragm, as noted fluoroscopically, is an additional manifestation of diagnostic value. A positive diagnosis can be made by x-ray if gas exists in the abscess cavity and is revealed on the film by the presence of a fluid level (Fig. 8). However, this situation will not be found in more than 20 per cent of cases. Aspiration should not be performed because of the danger of perforation of intestine, and hemorrhage. Pleurisy with sterile effusion on the affected side is the most common sequel and may be of diagnostic aid (Fig. 9). Other complications, such as rupture of the abscess into the pleural or free peritoneal cavity, are serious and are usually indicative of neglect.

As soon as the diagnosis is made, drainage should be instituted, provided the physical condition of the patient permits. Ochsner and associates (10) have emphasized the advisability of draining subphrenic abscesses extraserously, i.e., without entering the pleural or peritoneal cavity. Abscesses in the most common location, i.e., in the right posterior superior space (Ochsner), may best be drained



Fig. 9. Subdiaphragmatic abscess associated with pleural effusion. The dotted line represents the level of the right diaphragm. The shadow above the elevated diaphragm is caused by fluid in the pleural cavity—a common complication. This fluid usually remains sterile unless treatment is delayed or neglected; perforation through the diaphragm occurs under such conditions.

by excising the twelfth rib and incising into the subphrenic space at the level of the spinous process of the first lumbar vertebra. If the abscess is located anteriorly, it may be reached extraperitoneally by an incision along the costal margin, dissecting the peritoneum from the diaphragm upward until the abscess is reached. Only occasionally will it be necessary to drain through a lateral incision. Penicillin and other antibiotics should be given but are of little value in treatment of the abscess without surgery except that, no doubt, small abscesses will frequently be resolved. Likewise, as has been emphasized by Gerwig and Blades (11), antibiotics are surprisingly ineffective in preventing the formation of subdiaphragmatic abscesses.

3. *Intestinal obstruction* resulting from contractions of fibrous adhesions is not at all unusual and, if complete, may demand immediate release of the obstructed loop. Obstruction may be produced in this manner as early as three to four days following the onset of the peritonitis but usually occurs later (two to three weeks) and after the symptoms of the infection have become negligible. *Adhesions* which do not absorb are capable of producing obstruction, partial or complete, years after the attack of peritonitis. Except for intestinal obstruction, adhesions disclose little or no evidence of their presence. Details of intestinal obstruction are discussed in the following chapter. Fortunately, most of the obstructions occurring during the first few postoperative days can be relieved by intestinal decompression. Usually the relief achieved by decompression is only temporary, but in these early cases it is more often permanent, since the adhesions shrink or atrophy as the inflammation subsides.

4. *Pylephlebitis* or inflammation of the portal vein (accompanied usually by thrombosis) is an occasional and serious complication of peritonitis. The process may start in some of the extrahepatic tributaries of the portal vein and reach the major trunk by extension. One of the most reliable symptoms of pylephlebitis is the rather sudden occurrence of frequent chills along with an intermittent type of fever with sharp elevations and recessions. There may be few additional manifestations, perhaps icterus, tachycardia, slight abdominal tenderness, distention, signs of ascites, enlargement of the liver, and occasionally bleeding within the intestinal tract (see Ch. 31). Penicillin and one of the antibiotics active against gram-negative bacilli should be given as soon as the lesion is suspected. The disease, however, is extremely serious, and frequently results in death because of infection and portal obstruction.

5. *Pyogenic abscess* of the liver (see p. 667) may be encountered as a complication of peritonitis and, in most instances, is probably caused by an extension of the infection by way of the portal vein into the small intrahepatic tributaries. In many instances, the abscess formation will be multiple, in which case death almost always ensues. Suppurative cholangitis may likewise be responsible for multiple abscesses but is associated only with infections of the biliary tract. Multiple abscesses may coalesce into one large cavity, but when a single abscess is present it is usually caused by amebic infection. Operation is indicated as soon as the diagnosis of pyogenic abscess is made, in the hope that the abscess may be single and can be drained. Chemotherapy should be used as soon as the lesion is suspected. If the causative organism is a streptococcus or staphylococcus, good effects can be expected.

6. *Gastric dilatation* is a frequent complication of peritonitis as well as of abdominal operations in general; if untreated, it may produce damaging effects because of the mechanical pressure exerted upon the heart, lungs, and other viscera by the dilated stomach. The diagnosis should be suspected when there is persistent hiccup or frequent vomiting (or regurgitation) of small quantities of fluid. Gastric dilatation is in reality a part of the paralytic ileus which constantly accompanies peritonitis and, from a literal standpoint, perhaps should be considered as a manifestation and not a complication. Frequent gastric lavage or continuous "nasal suction" should be instituted.

7. There are numerous *miscellaneous complications* which may develop, many of which are extremely serious. Death from peritonitis is usually attributable to the systemic effects of the peritoneal infection with or without *septicemia.* As previously stated, *pneumonia* is a frequent complication of peritonitis, and commonly is a terminal feature.

Myocardial insufficiency, although secondary to other causes, is one of the main factors in the fatal termination.

OTHER VARIETIES OF PERITONITIS

Most of the clinical manifestations described in the previous pages of this chapter apply specifically to peritonitis secondary to perforation or contamination and largely caused by the colon bacillus. The following types of peritonitis are caused by different organisms and may present different clinical manifestations and therapeutic problems from the types of secondary peritonitis already considered. The infections produced by pneumococcus and streptococcus are the ones most frequently spoken of as *primary or idiopathic* peritonitis. In a study of 158 cases of primary peritonitis in children, Gross (12) found the hemolytic streptococcus to be the cause in 99, and the pneumococcus in 50.

1. **Pneumococcal Peritonitis.** This is a disease limited almost exclusively to children and occurs much more frequently in girls than boys. This latter feature has led some observers to conclude that the organism, on some occasions at least, gains access to the peritoneal cavity by way of the genital tract (vagina, uterus, and Fallopian tubes). This must be considered only one of the etiologic mechanisms, however, since pneumococcal peritonitis occurs as a complication of such diseases as upper respiratory infection, pneumonia, pleurisy, and nephritis, in which case it is blood borne. The length of time intervening between the onset of the original infection and the peritonitis varies from a day or two to many weeks, depending upon the severity and chronicity of the disease. Commonly, one of the first evidences of this intra-abdominal infection is the development of a diarrhea. The symptoms and signs are similar to those produced by the colon bacillus, except that the pain, even at the onset, is apt to be diffuse and poorly localized and examination reveals no local point of tenderness except in the late stage when an abscess may have formed. Vomiting is variable, at times being a prominent manifestation. The leukocyte count is markedly elevated. Palpation reveals diffuse tenderness with a doughy resistance but, in most instances, absence of boardlike rigidity. Occasionally, bulging is noted at the umbilicus (Fig. 10), representing nature's attempt to effect drainage. Blood culture may reveal the organism early in the disease. If much fluid is present in the abdomen, a carefully performed aspiration will be safe and will yield enough fluid from which smears and cultures will reveal the correct diagnosis. If aspiration is not feasible, or yields no fluid, it may be advisable to make a small exploratory incision under local anesthesia to obtain fluid for diagnostic purposes or to rule out appendicitis. Opinions differ as to the advisability of operation but Gross (12) favors a small incision for diagnosis and drainage. The character of the exudate in pneumococcal peritonitis varies but is usually thick, fibrinous, mucoid, greenish in color, and comparatively odorless. As soon as the diagnosis is made, chemotherapy is instituted with penicillin and antipneumococcus serum. Intestinal decompression with the nasal tube, administration of saline and glucose, and the like, as described previously in this chapter, may be indicated. Chemotherapy shortens the progress of the disease and minimizes the incidence of local abscesses.

2. ***Streptococcal Peritonitis.*** This type of peritonitis may occur as a postoperative complication; occasionally the streptococcus is the organism found in the pus produced by perforated appendicitis; however, it is more often encountered as an associated manifestation of respiratory diseases of some sort. Since streptococcal peritonitis is so commonly secondary to diseases treated effectively by chemotherapy, its incidence has decreased considerably in recent years. Occasionally no evidence of the original focus of infection can be found. The term "idiopathic or primary peritonitis" is therefore commonly applied to this type of infection as it is also to pneumococcal peritonitis, but perhaps correctly so only to the cases in which the portal of entry is not discernible and the infection is presumably blood borne. Except on occasions when streptococcal peritonitis is secondary to appendicitis or operative contamination, it is usually encountered only in children or infants (especially the latter). Regardless of the etiologic factor, the disease, before the days of chemotherapy, was

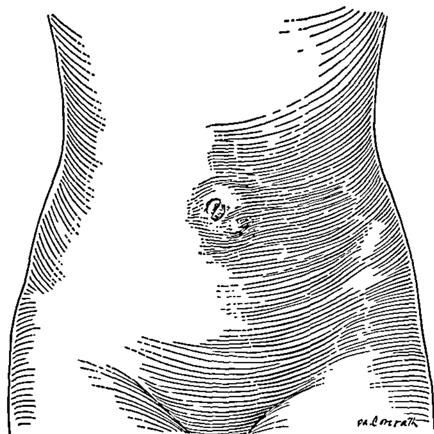


Fig. 10. Bulging at the umbilicus in pneumococcus peritonitis. This is nature's attempt to effect drainage; indeed, in neglected cases perforation occurs here with subsequent evacuation of an abscess cavity. This phenomenon occurs very uncommonly in any other type of peritonitis; it is usually a late manifestation, but in this particular instance occurred on about the third day of the peritonitis.

serious and associated with a high mortality. The manifestations are fulminating, and include practically all those encountered in peritonitis caused by *E. coli*. Because of the beneficial effect of chemotherapy, it is extremely important just as in pneumococcal peritonitis, that the diagnosis be made, resorting to a small exploratory incision for drainage and confirmation of diagnosis (12). An incision is often indicated because peritonitis due to appendicitis and other lesions requiring operation is difficult to exclude. In addition to chemotherapy, the various therapeutic measures, including parenteral fluids and gastric lavage, as described previously, should be instituted as indicated. The mortality rate in streptococcal peritonitis is in general higher than in the pneumococcal type, but should be low, if therapy is instituted early in the disease.

3. **Gonococcal Peritonitis.** This disease is confined entirely to females and is secondary to infection in the Fallopian tubes from which site the exudate containing the organisms (gonococci) breaks into the peritoneal cavity, but rarely ascends above the brim of the pelvis. There are always localizing signs in one or both of the adnexal regions, a manifestation which in itself should be sufficient to make a diagnosis, especially if a vaginal examination is made. Occasionally, however, if only the right Fallopian tube is involved the disease may be confused with perforated appendicitis. The peritonitis usually remains local and the patient does not appear as ill as in appendiceal peritonitis, even though there may be high fever and excruciating tenderness in the lower abdomen. The pulse rate is not as rapid and the face does not have the pinched, tired, and flushed appearance seen

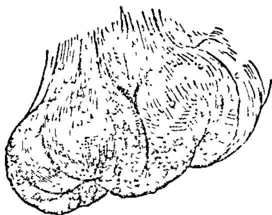


Fig. 11. Tubercles upon the peritoneum. (From Homans. Textbook of Surgery, Charles C Thomas.)

in patients with peritonitis caused by *E. coli*. Fatalities are rare. Occasionally, generalized abdominal rigidity, tenderness, and distention may be present which, however, subside spontaneously with the pelvic inflammation. The infection responds very well to penicillin, particularly if therapy is instituted early. Operations should not be performed in the acute stage; but months after the infection, it may be necessary to remove the Fallopian tubes, particularly in cases not receiving early penicillin therapy (see also Ch. 40).

4. **Tuberculous Peritonitis.** The invasion of the peritoneum by tuberculosis is usually secondary to local lesions in the lungs, mesenteric lymph nodes, cecum, appendix, or Fallopian tubes. Occasionally it is a manifestation of acute miliary disease. In many instances, it appears that organisms swallowed in sputum invade the intestinal wall (e.g., cecum), escape by way of the lymphatics of the mesenteric lymph nodes, and in this way give rise to a peritoneal infection.

Pathologically, the peritoneal lesions are quite variable. On some occasions numerous tubercles (0.5 to 1 mm. in diameter) are scattered about the peritoneum (Fig. 11), which is reddened, but otherwise unaffected. On other occasions, caseous masses are encountered and adhesions are present. Ascites is frequently noted, the fluid being clear and straw-colored, turbid, or even thick and purulent. The fluid invariably has a high specific gravity (about 1.015). There is no definite relation of the type of lesion to the duration of the disease, except that the type associated with tubercles and mild ascites without adhesions is frequently encountered early in the disease, and the caseous masses with adhesions late in the disease.

The *clinical manifestations* are extremely variable both as to type and severity. Occasionally, there is a rather acute onset with abdominal pain, nausea, and vomiting. This type is frequently confused with appendicitis and, at operation, will reveal tubercles scattered diffusely over a slightly reddened peritoneum associated, perhaps, with a small amount of clear, straw-colored fluid. However, usually the onset is insidious. Abdominal pain may or may not be complained of, but it is rarely severe. Gradually the abdomen becomes distended because of the ascites. Anorexia and nausea, but rarely vomiting, are complained of; there is a gradual loss of weight and an associated anemia, weakness, and malaise. Constipation or diarrhea may be present. Fever is extremely variable, but is usually moderately elevated in the afternoon and evening, receding to normal or subnormal by morning. The diagnosis is difficult and on most occasions is made only at operation. When found at operation, search should be made within the abdomen for the primary site.

Very important in *treatment* are streptomycin, isoniazid, and the other drugs found useful in tuberculosis; celiotomy does appear in many instances to have a mysterious curative effect regardless of whether or not a focus of the infection can be found and removed. For this reason alone, celiotomy appears justifiable in most cases, unless the presence of serious lesions elsewhere (e.g., lungs) contraindicates operation. In any case, diagnosis is thus made certain. However, patients with caseous areas and dense adhesions are rarely benefited by operation.

TRAUMA

Because of lawlessness, high speed automobiles, and the mechanization of industry, injuries to the abdomen which lead to peritonitis are becoming important surgically, especially since delay in treatment or a mistaken diagnosis may result in a fatal outcome. Civilian injuries of the type mentioned will be discussed here. War wounds of the abdomen are discussed in Chapter 42.

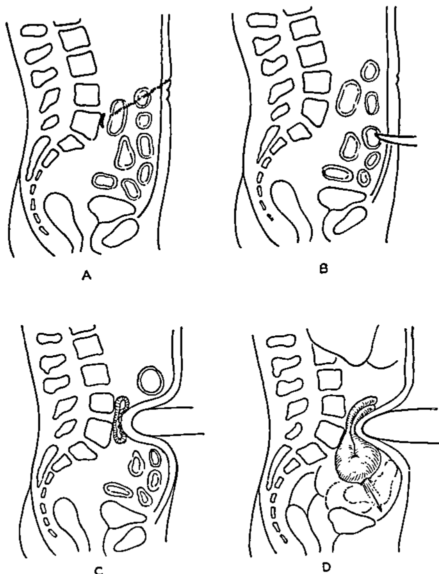


Fig. 12. Common mechanisms producing traumatic intestinal perforation. A, gunshot wound; B, stab wound; C, laceration of the intestinal wall by compression against the vertebral column by a blunt object; D, rupture of the intestinal wall by sudden compression of gas within the lumen.

1. **Rupture or Penetration of a Viscus.** Accidents resulting in perforation of an intra-abdominal organ, especially the intestine and bladder, may be sustained in one of three ways (Fig. 12): (*a*) A sharp object may penetrate the abdominal wall and perforate an intestine. Gunshot wounds of the abdomen are by far the most frequent example of this type of injury. Although the amount of bleeding resulting from a bullet wound of the abdomen is rarely sufficient to result in a fatal hemorrhage unless a major vessel is severed, in most instances a perforation of the intestine will be produced, which demands immediate repair because of the peritonitis which otherwise is bound to follow. (*b*) An intra-abdominal organ may be crushed and perforated, because of compression between two blunt objects or between a blunt object and the spinal column. In such a case there may be no external evidence of an intraabdominal injury or merely a slight contusion of the abdominal wall. (*c*) If a blow is sustained over the abdomen when the muscles are flaccid, there may be such a sudden and forceful expulsion of gas from one intestinal loop into another as to cause a rupture of the intestinal wall. A few instances of rupture of the colon

have been reported in which workmen have jokingly released compressed air near the anus of a fellow workman. The collapse resulting from a rupture of this type is profound in spite of the fact that little hemorrhage is produced, and most cases of this type are fatal, although operative therapy may be readily available and instituted. The serious effects are apparently due to the absorption of toxins (bacterial and otherwise) in the stool by the peritoneum.

The *clinical manifestations* of perforation or rupture of a hollow viscus, especially the intestine, are often overshadowed by the excitement of the occasion. However, severe *pain is experienced immediately unless the* patient is unconscious. A varying degree of shock, including such manifestations as tachycardia, weakness, and pallor, will be produced, dependent largely upon the amount of hemorrhage accompanying the intestinal injury. Local signs may be minimal at first, i.e., at a time when operation should be done. The most constant local signs are tenderness and muscle spasm which at first are confined to the injured area but soon spread to the rest of the abdomen. Unfortunately, as Musselman and associates (13) have emphasized, the early signs of rupture of the ileum and colon are less dramatic than those encountered in perforation of a duodenal ulcer. The surgeon must recognize the early minimal signs because waiting for frank signs of peritonitis before deciding to operate will usually result in so much delay that recovery will not take place. Tenderness is rather constant at the outset, but muscle rigidity may not be present for several hours. Nausea and vomiting will occur sooner or later, unless operative repair is instituted before vomiting takes place. An x-ray of the patient in the upright position may reveal gas under the diaphragm, a finding which is diagnostic of rupture of intestine or stomach. After a few hours, the leukocyte count becomes elevated, but fever is not present until the peritoneal contamination takes on the features of peritonitis (18 to 24 hours). Of the signs mentioned above, muscle rigidity, if present to a significant degree, is one of the strongest indications for operative intervention, so long as one can eliminate voluntary spasm, rigidity due to injury of the abdominal wall itself, and reflex spasticity from skeletal fracture, especially of spine or ribs. It should be emphasized, however, that for several hours after perforation of a viscus, particularly gunshot wounds of the stomach and small intestine, there may be an almost complete absence of gastrointestinal manifestations, including vomiting and muscle spasm; frequently, they are overshadowed by the evidence of prostration or primary shock. For this reason, the clinical manifestations are not nearly as important in deciding the question of operation as in the location of the wound, which is then the chief factor leading to the decision as to whether or not the *peritoneal cavity has been penetrated.*

Perforation or rupture of the bladder, ureter, or kidneys will present symptoms and signs similar to, but perhaps less severe than, those mentioned above. Diagnosis can usually be made readily by examining the urine for gross blood. The inflammation of the peritoneum produced by urine escaping into the peritoneal cavity may be conducive to the development of peritonitis and this complication may be the most important factor in the cases terminating fatally, especially those not treated by operative repair. On rare occasions, rupture of the base of the bladder or urethra may produce *extravasation of urine* into the subcutaneous tissues of the abdominal wall. This is a serious complication which may require expert judgement in its therapy; it is discussed in detail in Chapter 41.

The *treatment* of a ruptured viscus is, of course, surgical; the earlier the operation is performed (assuming the patient's physical condition permits it) the more likely is it to be followed by success. Indeed, when a penetration of the peritoneal cavity is produced (gunshot or stab wound), laparotomy is performed without regard to the presence or absence of the manifestations mentioned above. If shock is present and is not due to injuries elsewhere, it may be treated by transfusions or fluids while the operation is in progress as discussed under Intraperitoneal Hemorrhage. Occasionally, gunshot wounds of the abdomen are sustained without perforation of an intestine. The severity of the symptoms is much less pronounced in such instances, but the possibility of intestinal perforation is still

so great that the surgeon deems it unsafe not to perform a celiotomy; if the bullet has traversed any part of the peritoneal cavity in which a hollow viscus is normally present, an operation must be performed.

At operation, simple closure of perforations (whenever possible) is preferable to resection. Thorough search for puncture wounds and injury to viscera, including the retroperitoneal portions of the intestines, must be made. All free food or feces are removed gently by suction or with a moist sponge. If the large bowel is perforated or injured seriously, it is frequently safer to exteriorize the area than to close it by suture. If the bowel cannot be exteriorized, a colostomy will often be indicated. Drains are not indicated except occasionally down to the site of repair in the bowel. After operation, transfusions are given as indicated; intestinal decompression is maintained for 24 to 72 hours and adequate fluids are supplied. Oral intake of food is started slowly. Penicillin may be given prophylactically for two to four days in severe injuries.

The mortality rate in gunshot and other penetrating wounds of the peritoneal cavity is high and, in intestinal perforation particularly, is usually directly related to the length of time intervening between injury and operation. For example, in perforation of the small bowel, Musselman and associates (13) noted that when the interval was 6 hours or less the mortality rate was 15 per cent, between 6 and 12 hours it was 35 per cent, and between 12 and 24 hours it was 80 per cent. Peritonitis and hemorrhagic shock are the two most common complications causing death.

2. **Intraperitoneal Hemorrhage.** In most instances, intraperitoneal hemorrhage arises from rupture of an organ (e.g., the liver or spleen), but in penetrating injuries (such as gunshot and stab wounds), any large vessel may be the source of the bleeding. Crushing injuries or direct blows sustained over the abdomen may produce a laceration of the capsule of the organ and the parenchymatous tissue as well.

The *clinical manifestations* of hemorrhage of the type described above may be identical to shock produced by any severe hemorrhage (see Ch. 13). Pallor, tachycardia, weak and thready pulse, cold sweat, and mental dullness are some of the important manifestations observed. If the hemorrhage takes place rapidly "air hunger" may also be present. In addition, there are usually at least a few of the symptoms and signs of peritoneal irritation. A diffuse tenderness is present which, as a rule, is no more pronounced over the organ injured than in the rest of the abdomen. Muscle spasm is rarely as marked as it is when an intestine is perforated or ruptured. Likewise, nausea and vomiting are apt to be absent. Mild distention may develop and percussion may reveal a shifting dullness. If the abdominal findings are of such a trivial nature as to make the diagnosis of intraabdominal injury appear unlikely, important information may be gained by hourly observation of the erythrocyte count, and hematocrit and hemoglobin determinations. If the hemorrhage is significant, within a few hours there is usually (but by no means always) a sufficient drop in the above determinations to differentiate the condition from simple trauma and shock. Aspiration with a blunt needle may be very helpful in detecting intraperitoneal hemorrhage; however, if no blood is found, the presence of blood cannot be excluded. It might appear that accidental puncture of the intestine with subsequent leakage and peritonitis would take place; but in experienced hands, this is extremely rare.

If the hemorrhage is of sufficient magnitude to produce symptoms of shock which are not improved in an hour or two by two or three transfusions and other supportive measures, it is usally safe to assume that bleeding is still active. On such occasions, immediate operation is usually indicated, treating the shock with constant transfusion during the operation. On many occasions, the differentiation between hemorrhage and perforation of the intestine is so difficult that the latter possibility of itself will demand laparotomy. At operation any laceration of the liver or spleen should be repaired by suture, except that in lacerations of the spleen it is better to remove the organ than to attempt to repair the damage. If bleeding is severe, transfusions must be started early, continued throughout the operation, and repeated postoperatively as indicated.

Intraabdominal apoplexy is a term applied

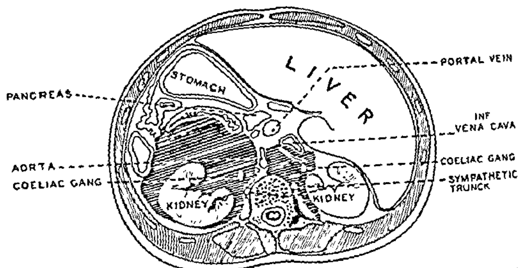


Fig. 13. Two common sources of retroperitoneal hemorrhage. On the left side is shown a blood clot arising from a lacerated kidney; on the right the hemorrhage is produced by a fracture involving the transverse process of the vertebra. In each case the clot infiltrates anteriorly. Note the close proximity of the blood clot to the numerous nerve trunks, ganglia and peritoneum of the posterior wall of the abdomen; this presumably accounts for the production of manifestations which are so similar to those produced by inflammation of the peritoneum.

to spontaneous hemorrhage from vessels in the peritoneal cavity. It is rather uncommon but may produce severe shock and require immediate operation. It occurs most commonly in men in the latter decades of life. Many of the patients will have hypertension or arteriosclerosis. Mild abdominal pain is complained of but, as in other intraabdominal hemorrhage, very little muscle spasm or tenderness will be found. The source of such hemorrhage is usually a mesenteric vessel, although it may occur in the retroperitoneal space and be manifested as a large mass (hematoma).

3. **Retroperitoneal Hemorrhage.** There are two common sources of hemorrhage of this type; 1. laceration of the kidney; and 2. fracture of, or severe injury to, the spine (Fig. 13). Occasionally, injury to the soft tissues in the back may be sufficient to produce a retroperitoneal hemorrhage. The similarity of the symptoms produced by retroperitoneal hemorrhage and early peritonitis was emphasized by one of us years ago (14). All the manifestations of peritonitis, including pain, muscle spasm, nausea, vomiting, and leukocytosis, may be produced by a hemorrhage of this type. Distention develops as in peritonitis, but muscle spasm is less marked, often being no more than a doughy resistance. It is difficult to explain the development of these symptoms in such an instance, but it seems apparent that the hematoma and the trauma located in this area may involve the nerves (sympathetic and somatic) which are important in the production of such symptoms. The surgeon may have ample evidence of damage to the kidney or spine (e.g., blood in the urine, x-ray of the spine showing fracture), but the symptoms may be so suggestive of intestinal injury that failure to perform an exploratory laparotomy is considered unsafe. However, in most instances, differentiation can be made on the basis of severity and number of manifestations; in general, vomiting and tachycardia are less pronounced in retroperitoneal hemorrhage. Moreover, the patient does not appear so ill in retroperitoneal hemorrhage; the expression is less apprehensive and the face less pinched. Conservative therapy is obviously indicated in the absence of injury to a viscus or large vessel, thus avoiding the damaging effects of a celiotomy.

MISCELLANEOUS DISEASES ASSOCIATED WITH THE PERITONEUM

One of the most important of these is *malignant disease*, because it may occur in almost any organ within the abdomen and may involve the peritoneum secondarily. The

invasion of the peritoneum by the tumor (e.g., carcinoma) is noted as one or many tiny, irregular, hard nodules which become attached to the deeper tissue as they enlarge and likewise attach themselves to adjacent organs by malignant tissue or adhesions. The peritoneum may likewise become involved by extension of the tumor toward the periphery of the organ. Invasion of the peritoneum by extension or metastasis is accompanied by the development of free fluid, which at first is clear but rapidly becomes bloody. With a relatively few exceptions the presence of bloody fluid in the peritoneal cavity is quite pathognomonic of the presence of malignant disease involving the peritoneum.

Ascites. This is encountered in many other conditions besides malignancy. It is associated, also, with such diseases as myocardial insufficiency, nephritis, and cirrhosis of the liver. In such instances, however, the fluid is practically always clear and, being a transudate, will have a low specific gravity. The presence of a large amount of ascitic fluid in the peritoneal cavity often produces a degree of distension which is occasionally differentiated with difficulty from the distention due to a tumor or even a slowly developing paralytic ileus. Ordinarily, however, palpation and percussion will reveal the true nature of the abdominal tumor. If the fluid is evacuated by a trocar (paracentesis abdominis) or by a laparotomy, much information may be gained by its physical characteristics. The most common lesions producing bloody ascites are carcinomatosis of the peritoneum, trauma, ruptured ectopic pregnancy, intestinal strangulation, volvulus, twisted pedicle of an ovarian cyst, and acute pancreatic necrosis. In doubtful cases, a small incision under local anesthesia will not only evacuate and reveal the nature of the ascites, if present, but will also provide a view of the peritoneum and omentum; often a biopsy of diseased tissue can be obtained, thereby establishing the correct diagnosis. This cannot be achieved by simple aspiration, a procedure, moreover, which is apt to be damaging if distended bowel rather than ascites is the cause of the swelling.

Hernias. With very few exceptions, hernias are associated with abnormalities of the peritoneum, are frequently secondary to congenital defects, and may be roughly divided into external and internal types (see Ch. 34).

Retroperitoneal Space. Diseases and injuries of the retroperitoneal space are important because of the confusion with similar conditions in the peritoneal cavity. Most important is the kidney. Fortunately, with the aid of pyelography (intravenous or cystoscopic), the kidney can be identified quite readily as the cause of disease. Neurocytomas, especially those arising in the adrenal are occasionally observed, particularly in children. Occasionally, serious tumors (lymphosarcoma) arise in the retroperitoneal lymph nodes. By the time they are discovered, they are rarely operable. Benign tumors, such as lipomas, have been reported. *Retroperitoneal abscesses* may develop (from the kidney, spine, and lymph nodes) and may present laterally or in the neighborhood of the inguinal ligament.

Diseases of the Mesentery. No doubt the most common lesion affecting the mesentery is *lymphadenitis* of the nodes within the mesentery. These may obviously be pyogenic (as described on p. 799) or tuberculous. In either case, suppuration may take place and lead to peritonitis, adhesions, and the like. Rarely, however, is the blood supply to the intestine jeopardized. *Cysts* of the mesentery are encountered occasionally. They are located near the junction of the mesentery and intestine and are frequently so intimately connected with the wall of the intestine that removal can be achieved only by resection of a segment of intestine. Occasionally, they compress the intestine so much that a partial obstruction is produced. When the cyst is so large and extends so far posteriorly that excision is not possible without injury to large vessels, marsupialization should be performed. *Cavernous lymphangiomas* have been encountered in the mesentery but are extremely rare. *Sarcomas* are likewise very rare and will be operable only when encountered at an early stage.

Diseases of the Omentum. Perhaps the most common lesion of the omentum is *inflammation*. Naturally, it may be affected secondarily when surrounding an inflamed appendix or other source of infection. Resolution without abscess formation in the omentum itself usually takes place. Occasionally,

inflammatory masses develop in the omentum without an obvious primary lesion; they may produce abdominal pain, tenderness, nausea, leukocytosis, and other symptoms of sufficient magnitude to lead the surgeon to a laparotomy. Resection is performed readily and relieves the condition. *Torsion of the omentum* is occasionally encountered as a complication of a hernia when the omentum is adherent to certain portions of the sac. More rarely it will be found within the peritoneal cavity, not associated with a hernia. In either case, abdominal pain and other mild symptoms may lead to laparotomy. Resection of the portion of omentum involved is indicated. *Tumors* of the omentum may be cystic or solid; each group is rare. Of the solid tumors, sarcoma (fibrosarcoma or lymphosarcoma) is most common. The only significant manifestation except in the terminal stage may be the presence of a mass. Resection may be possible. *Cysts* of the omentum, usually lymphatic in origin, are encountered but likewise are rare. Excision is simple and curative.

Chylous Ascites. This is a rare condition but is discussed here because of its surgical importance; up to 1954, Hoffman (15) found only 24 reported cases. In this group, the etiology was unknown in 10, due to trauma in four, due to demonstrable thoracic duct obstruction in three, and due to intestinal obstruction in three cases. In the majority of these cases the symptoms developed acutely, resembling those of acute appendicitis or perforated peptic ulcer. Nausea, vomiting, rebound tenderness, muscle spasm, and pain on palpation are common manifestations, although occasionally symptoms are minimal, consisting primarily of abdominal distention (with chyle). Leukocytosis is common (16). The disease is self limited; accordingly, no surgical treatment (such as ligation of the duct) is indicated, although the temporary drainage afforded by operation appears to improve the patient. All except one of the 24 patients reviewed by Hoffman recovered, and the one fatal case was a patient who had been acutely ill for four days and was almost moribund when he came into the hospital.

Talcum Powder Granuloma. Reference has already been made (Ch. 14) to the foreign body reaction resulting from talcum powder which is used as a lubricant on surgical gloves. When this granulomatous process develops in the peritoneal cavity, abdominal pain may become very troublesome. At operation, numerous adhesions are found associated with the granulomas which surround the talcum powder granules. Symptoms may persist almost indefinitely. To prevent this, almost all surgeons have abandoned talc in favor of some type of starch product for use in lubricating hands and surgical gloves. However, starch likewise causes granulomas occasionally; accordingly, it should be thoroughly washed off the gloves before the surgeon begins operating.

Porphyria. Although this disease is comparatively rare, it is described in slight detail here because so few physicians are familiar with it, and the condition is so important to the surgeon. Manifestations, including nausea, vomiting, abnormal tenderness, and muscle spasm, may present the same features as indicated in acute appendicitis, perforated ulcer, and so forth. It is a metabolic dysfunction of porphyrin metabolism. The porphyrins (17) are constituents and catabolic products of such substances as hemoglobin, myoglobin, and chlorophyll, all of which are concerned with cellular respiration. In porphyria there is an interruption in the process of synthesis, or breakdown of hemoglobin, resulting in the accumulation in the body and excretion in the urine of abnormal porphyrins. Watson (18) has divided the syndrome into three forms: 1. light sensitive; 2. acute intermittent, or acute idiopathic; and 3. mixed, with characteristics of Types 1 and 2. Types 1 and 2 are rare but may be present with hemolytic anemia. Type 2 may be encountered after infection, trauma, and drug therapy. Type 1 is usually found in infancy, Type 2 in adolescence, and Type 3 after adolescence. It is a familial disease. The most significant diagnostic manifestation is the passage of dark amber or dark red urine intermittently, although usually the color is not manifested until the urine has been standing exposed to sunlight.

"The diagnosis of acute intermittent porphyria is confirmed by the demonstration of porphobilinogen, uroporphyrin, or other abnormal porphyrins by one of the four following tests: 1. the Watson-Schwartz test for

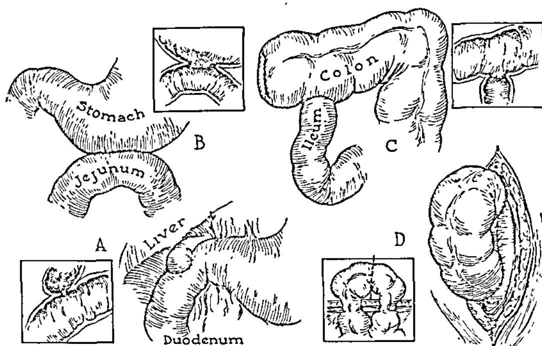


Fig. 14. Common types of intestinal fistula produced by operative means. A, cholecystoduodenostomy, performed usually for carcinoma of the pancreas or inoperable carcinoma of the ampulla of Vater; B, gastrojejunostomy, utilized in stenosis of the pylorus or duodenum; C, ileocolostomy, commonly performed in resection of the proximal colon for carcinoma; D, double-barreled colostomy, as performed to correct obstruction in inoperable carcinoma of the rectum. On the second or third day the sigmoid is cut across, as shown by the dotted line in the insert.

urinary porphobilinogen; 2. exposure of acid urine to sunlight; 3. spectroscopic examination of the urine (19); and 4. determination of melting point of urinary porphyrins," as indicated by Furste and Ayres (20). The latter authors have warned that pathologic conditions, such as acute appendicitis, may occur during an attack of acute intermittent porphyria. Accordingly, the surgeon must be aware of the possibility of these two conditions being present simultaneously. Melby and associates (21) have reported the effective use of chlorpromazine (25 mg. three or four times per day) in nine cases of acute intermittent porphyria.

Fistula. A fistula is an abnormal communication between epithelial or endothelial lined surfaces (usually hollow viscera) or a communication between a viscus and the exterior. They may be produced in several different ways.

1. Occasionally the communication may be *congenital*, that is, result from a defect in fetal development. Rectovaginal, rectovesical, and rectal fistulas are often associated with an imperforate anus.

2. *Postoperative fistulas* may be divided into two types. In the first group (*a*) the fistula is produced intentionally, connecting one viscus with another for functional reasons, e.g., cholecystogastrostomy, ileocolostomy, or gastroenterostomy (Fig. 14); (*b*) in a second group of cases, the fistula opens to the outside through accidental or intentional means, e.g., urinary fistula or biliary fistula. Pancreatic fistula and duodenal fistula likewise occur and develop most commonly following operation of the duodenum. A biliary fistula which persists is usually due to an obstruction distal to the opening. In a *fecal fistula,* the intestinal content is diverted to the outside; it is frequently performed intentionally, e.g., colostomy, preliminary to a resection of a carcinoma of the rectum. When a fecal fistula results accidentally it usually occurs because of a rupture of an intestinal suture line, which in most instances is caused by an obstruction distal to the operative site.



Fig. 15. Multiple sinuses and fistulas of the abdominal wall. Fecal material drains from only one of the openings. The lesions are of three years' duration and followed a pelvic operation. The patient was operated on and the involved areas resected. Recovery was uneventful. Ordinarily if a fecal fistula does not heal within six months, operation is advisable.

(Frequently, such a leak of intestinal contents produces a fatal peritonitis before a fecal fistula develops.) On most occasions, fistulas which develop in the absence of obstruction will close spontaneously; they may drain for months, however (Fig. 15). If the fistula is located high in the intestine, it will usually not heal spontaneously; furthermore, it may result in the digestion of the skin or the walls of the wound, causing severe pain unless treatment is instituted promptly. In addition to the methods of formation as described, a fecal fistula may also develop because of union of the skin with the intestinal mucosa. Treatment of fecal fistulas is considered below and elsewhere.

3. Fistulas caused by tissue destruction due to severe *infection* are extremely common, as clearly illustrated by the rectal fistula which forms as a complicating aftermath of a rectal abscess.

4. Fistulas may be of *mechanical origin*. A vesicovaginal communication may develop as the result of pressure necrosis during childbirth. A cholecystenterostomy may be formed by the passage of a gallstone from the gallbladder into the intestine.

5. Occasionally, a *malignant tumor* may be responsible for the development of a fistula. An intestinal operation performed through malignant tissue may produce a permanent fecal fistula leading to the exterior, if the patient does not first succumb to peritonitis caused by the leak in the suture line.

The *treatment* of fistula depends upon its location and cause. If the communication has followed some type of infectious process, excision of the fistulous track and closure of the opening in the viscus will usually effect a cure. A fistulous communication between two loops of intestines may be cured by dissection of the walls from each other, excision of inflammatory edges, and closure of the openings. Resection of the affected loops followed by an anastomosis may be necessary. The edges of the opening in the intestine must be inverted, since union will occur only when the peritoneal surfaces are approximated. A fistula produced by malignant tumors cannot be cured by closure with sutures but may be

eliminated if the growth can be completely excised and the resultant defect repaired with complete obliteration of dead space at the site of excision.

As already stated, most fecal fistulas, with the exception of those high in the intestinal tract, will heal spontaneously unless there is an obstruction distal to the fistula. If such an obstruction is present, it will obviously have to be corrected by operative means before the fistula will close. If the fistula persists because of attachment of the intestinal mucosa to the skin, an operation consisting of division of the union between mucosa and skin with inversion of the intestinal mucosa should result in a cure. Occasionally, such a repair will produce so much narrowing of the intestinal lumen that either obstruction or a recurrence of the fistula will result. On such occasions, resection of the defect, with an anastomosis between the two loops (proximal and distal) of intestine is indicated. When skin irritation develops, as it usually does in high small bowel fistulas, prompt and effective treatment will be indicated to prevent the severe pain and loss of morale which develops commonly. Many remedies have been recommended, but few are effective. Constant aspiration of the intestinal contents as they are extruded will relieve the irritation, particularly if powdered aluminum is sprinkled (twice a day) over the irritated skin, after it is thoroughly washed and dried.

As will be noted in the legend for Fig. 14, the suffix "*ostomy*" is commonly utilized to signify a fistulous communication between different organs of the body (especially intra-abdominal). The term implies the opening of an organ without closure, but establishment of communication with another organ or the exterior. The suffix "*otomy*," however, implies the opening of the organ or viscus and closure without establishment of a fistulous tract. When the suffix "*ectomy*" is used in connection with an organ or tissue, excision of that organ or tissue is implied.

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33

INTESTINAL OBSTRUCTION

General Considerations
Specific Lesions Producing Intestinal Obstruction

In the continental United States about 5,000 deaths are reported annually as due to intestinal obstruction, in addition to an equal number attributed to hernia. The number has remained unchanged over the course of many years despite increasing knowledge and better diagnostic and therapeutic technics. The challenge for improvement in this field is therefore real. Before discussing specific lesions which produce intestinal obstruction, a few general considerations will first be considered.

GENERAL CONSIDERATIONS

Definitions. In the medical literature of the world the old designation generally applied to intestinal obstruction of all types is *ileus.* In this country at least, it is used to define a remarkable condition in which there is no actual organic obstruction but in which the intestinal contents are stagnant as if the lumen were occluded. Because this condition is produced by a cessation of intestinal peristalsis by one of several causes, usually general peritonitis, it is called and will be referred to in this text as "paralytic ileus." In contrast to paralytic ileus are the cases in which there is an actual organic obstruction. These comprise a great variety of lesions which may be divided into two general groups, the first of which will be called "simple mechanical obstruction." In this group, only the lumen of the intestine is primarily occluded. In the second group, called "intestinal strangulation," an occlusion of the mesenteric blood supply is of primary significance and indeed creates an acute surgical emergency, as discussed below. Anatomic causes, such as bands and adhesions, may produce either of these two latter types. Other anatomic causes, such as mesenteric thrombosis, intussusception, and volvulus, are defined and described separately later in the chapter. Other designations often used are high obstruction and low obstruction, indicating as a rule the level at which the obstruction has occurred. High obstruction usually indicates an occlusion at the pylorus, duodenum, or upper jejunum. Low intestinal obstruction is usually limited to the large bowel, so that a better designation is large bowel obstruction, as contrasted to small bowel obstruction. Acute is much more important surgically than chronic intestinal obstruction and most of the chapter will therefore be devoted thereto. Acute intestinal obstruction is produced by a sudden cessation in the passage of intestinal contents whereas chronic obstruction refers to partial or intermittent occlusion.

Classification. Acute intestinal obstruction is classified with difficulty as might be inferred from the many terms in common use. This difficulty is increased because a combination of elements is often present in each individual case, particularly when symptoms have been present several days. Nevertheless, for practical reasons, acute intestinal obstruction will be divided into three groups based on three distinct pathologic differences, at least in the beginning of the disease. In two of these three groups, an actual obstruction to the intestine is present; in one, the obstruction involves the lumen alone, in the other, the blood supply as well. In the third group, the intestine is not obstructed but merely unable to propel its contents. The terms used in these three groups are as follows:

1. Obstruction to the intestinal lumen from a band, tumor, stricture, or adhesion,

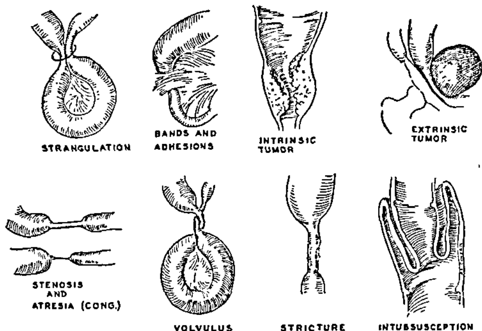


Fig. 1. Eight common causes of intestinal obstruction. Note the various mechanisms producing occlusion of the lumen as well as blood supply. Though not indicated strangulation includes volvulus and intussusception; bands and adhesions may also produce strangulation.

creating merely a simple mechanical obstruction.

2. Obstruction to the blood supply (intestinal strangulation) from a band, hernial sac, adhesion, or thrombosis, creating simultaneously intestinal obstruction.

3. Paralytic ileus, secondary to peritonitis, trauma, or other causes in which there is really no organic intestinal obstruction.

The three groups represent definite clinical types, but the classification is inexact anatomically for several reasons. Thus, the same obstructive agent may produce differences in the response of the intestine; there is more than one factor in the individual case; and, finally, the sequence of events varies after the onset of obstruction. Moreover, in any type of intestinal obstruction the status of the intestine and mesentery (of which the most significant are the patency of the lumen of the bowel, the activity of the intestinal musculature, and the integrity of the blood supply) is important, yet hard to evaluate clinically. Nevertheless, it is valuable to view each individual case in terms of such changes as well as of the three groups mentioned above.

Of the many anatomic causes, a few are represented in Figure 1. In the first group occluding the lumen only (proceeding from above downward) are esophageal stricture and cancer, gastric carcinoma, pyloric stenosis, small intestinal bands, adhesions, enteroliths, large bowel cancer, adhesions, and fecal impaction. Extrinsic agents, such as tumors or abscesses, may occlude the lumen at any level; the same is true of strictures of various kinds. In the group producing primarily intestinal strangulation are hernia, intussusception, volvulus, and mesenteric thrombosis. The third group or so-called paralytic ileus occurs in mild form after laparotomy and in a severe form in general peritonitis, presumably as a reflex phenomenon, after injury to the spine and other extensive skeletal trauma, or as a manifestation of potassium deficiency, or with serious extraabdominal disease, e.g., pneumonia, meningitis, nephritis.

Incidence. Three or four decades ago strangulated external hernia was by far the most common cause of obstruction, constituting as much as 40 to 45 per cent of the total number. This incidence has decreased sharply of recent years, partly because hernias are operated upon at an earlier date.

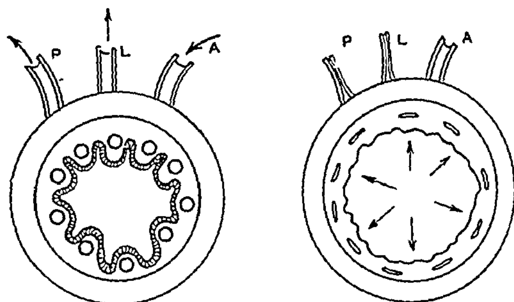


Fig. 2. Diagrammatic cross section of small intestine. Left, under normal conditions; right, under the influence of increased intraluminary pressure produced by a simple mechanical obstruction. Note that the vessels in the submucosa are flattened and that the mucosa is not represented because its viability has been destroyed by pressure. Although the arterial flow (A) is indicated as normal in contrast to the impaired portal (P) and lymphatic (L) flow, the arterial flow is impaired even before the venous flow. In any case, absorption can occur only through the serosal surface unless the intraluminary pressure falls enough to permit absorption into the blood stream. More important in producing sudden "toxic" absorption is a similar release of the vascular obstruction itself as in reduction of intussusception or volvulus, or on cutting the neck of the sac in a strangulated hernia.

Moreover, due to the increase in life span, carcinoma has increased, as has the obstruction due to adhesion because abdominal operations are increasing. Wangensteen (1) reports that in 1,262 cases of obstruction occurring between 1942 and 1953 at the University of Minnesota Hospital, 31 per cent were due to adhesions; in an additional 7 per cent, obstruction due to "operative complications" (presumably fresh adhesions) was recorded. Malignancy was the cause in 27 per cent and external hernias in only 12 per cent. Other clinics are reporting similar figures.

Pathology. Intestinal obstruction due to organic lesions produces pathologic changes which may be divided into those which are local and those which are systemic. The pathology of paralytic ileus is described separately for reasons already mentioned.

1. The local *changes* following intestinal obstruction are caused by two separate mechanisms, occlusion of the intestinal lumen and occlusion of the blood supply. Each of these mechanisms, however, is often involved to a varying degree in a particular case, as will be apparent from the following description.

(*a*) Occlusion of the intestinal lumen is one of the first effects of acute intestinal obstruction, whatever the cause may be. Although the occlusion may be partial at first, it soon becomes complete because of local changes brought about by the vigorous attempts on the part of the bowel to force intestinal contents past the barrier. Wave after wave of peristalsis (accentuated by the ingestion of food and especially of cathartics) beat against the narrowed lumen and succeed perhaps in forcing contents through for a time. Soon, however, the bowel above dilates (Fig. 2) and bacteria multiply in the stagnant contents. The bowel wall becomes edematous which may make the partial obstruction complete or the weight of the fluid above the obstruction may kink the bowel, completely obliterating the lumen.

In general, the subsequent changes are due to an increase in the accumulated obstructed bowel contents by swallowed air, intestinal secretions, and as the result of bacterial multiplication. The increased intraintestinal pressure thus produced distends the bowel more and more. The more regurgitation of bowel contents into the stomach leads to



Fig. 3. Strangulated, gangrenous small intestine due to an extensive volvulus. The lesion developed as a terminal manifestation in a patient with an extensive carcinoma of the lung. Nausea was present but no vomiting; severe prostration and circulatory failure developed shortly after the onset of abdominal pain. The photograph was made at the time of autopsy; note the striking difference in color between the normal viable gut, and the gut which is strangulated.

vomiting the less the bowel dilates. On the other hand, if the distention is unrelieved and becomes great enough, the blood flow through the bowel becomes occluded and loss of viability and even necrosis, first of the mucous membrane and then of the entire wall, may occur (2). This necrosis, though relatively uncommon, is similar to that in intestinal strangulation, which is described next, and thus explains how, even in simple mechanical obstruction of the lumen, the local effects in neglected cases may be the same as those produced by strangulation.

(*b*) *Occlusion of the blood vessels, or intestinal strangulation,* occurs frequently in intestinal obstruction, developing quite rapidly and coincidentally with the occlusion of the intestinal lumen in intussusception, volvulus, and strangulated hernia. Occlusion of the lumen may indeed precede by several hours occlusion of the blood supply. Conversely, as just described, simple occlusion of the intestinal lumen, if neglected and accompanied by severe distention, will impair blood supply and thereby produce the same, though perhaps less extensive and certainly slower, tissue changes as strangulation.

After a few hours, tissue injury in complete strangulation develops rapidly and is soon followed by necrosis and gangrene (Fig. 3). Since the bowel lumen contains many and virulent bacteria, infection rapidly sets in and the strangulated intestine then acts as any area of gangrene accompanied by a severe infection. The influence of bacterial growth has been convincingly shown by Cohn and Rives (3). Absorption of toxic material thus produced is most rapid when the gangrenous tissue is free in the peritoneal cavity, as in a case of complete volvulus. Rarely is direct absorption prevented by walling off by the omentum; in strangulation by hernia, the sac is usually so tight as to constitute an effective walling off of this sort. The gangrenous process may be so acute and rapid that the associated occlusion of the lumen, though nearly always present, is completely overshadowed by the effects of the strangulation.

2. The *systemic effects* of intestinal obstruction are also produced by two separate

mechanisms: (*a*) dehydration from loss of water, electrolyte and plasma protein, and (*b*) toxemia from absorption of infectious or other material present in strangulated bowel. Both of these mechanisms are sometimes so closely associated as to be indistinguishable clinically. Their pathogenesis, however, is so different that they will be discussed separately.

Distention in itself, it should be emphasized, regardless of the cause, may produce many of the systemic effects described below. Thus no systemic effects may follow a complete occlusion of the intestines provided distention is prevented in the absence of strangulation or of water and electrolyte deficits. Moreover, distention may result not only from occlusion of the intestinal lumen but also from inability of the musculature adequately to contract, as well as from other nervous and vascular factors, and still lead to the clinical picture of dehydration.

(*a*) *Dehydration* as mentioned before (see Chap. 9) is probably an inexact term to describe the systemic effects resulting from failure to replace the abnormal loss of gastrointestinal secretions which, of course, varies in content of electrolytes as well as water. The loss commonly takes place because of vomiting, which is a frequent symptom in intestinal obstruction. Distention in itself may result in vomiting from reflex action, whether the lumen is occluded or not; this has been experimentally demonstrated by abolition of vomiting through section of the nerves to the involved segment of the bowel. On the other hand, distention often follows because the obstructed contents are not vomited but, instead, accumulate in the dilated bowel. Moreover, distention sometimes aggravates the loss of water and electrolyte by stimulating secretion, thus increasing dehydration. It should be emphasized, therefore, that dehydration follows failure to replace the loss of fluid into obstructed bowel whether it is vomited or not; thus the actual amount of vomitus may not give a clear indication of the total amount of fluid lost into the obstructed stomach or intestine. Many liters have actually been measured in obstructed intestines.

To the loss of intestinal contents which contain only water and electrolyte, must be added the loss of fluid into the wall of obstructed bowel and into the peritoneum. This fluid differs from gastrointestinal secretions because it contains protein which approaches the concentration of that found in the plasma. Indeed, the term plasma dehydration may be used to describe this type of loss. Its mechanism is similar to that observed in peritonitis and burns, as described elsewhere.

The clinical picture of *dehydration* varies widely. The patient may be merely prostrated or, in the late neglected states, may be comatose. Surgical shock is found only when the loss of fluid has been extensive and rapid, especially if accompanied by extensive depletion of the plasma. The skin everywhere is dry and inelastic, the mouth is parched, the tongue is coated and furred, the lips dark red in color. Examination of the blood will reveal a hemoconcentration provided the red count was normal before; a red count of six or seven million per ml. is not uncommon and should obviously not be confused with a blood dyscrasia such as polycythemia. Blood chemical study may reveal pronounced changes, such as loss of chloride (hypochloremia), loss of sodium (hyponatremia), an elevation of the nonprotein nitrogen, a change in the CO_2 combining power of the blood (indicating either acidosis or alkalosis, depending on various factors), and alterations in the serum protein. If the dehydration has been due to loss of water and electrolyte alone, the plasma protein will show the same trend as the red count and hyperproteinemia may be found. However, if plasma has been lost in considerable amount, the plasma protein concentration will either be normal or below normal.

High intestinal obstruction because of the usual greater loss of fluid by vomiting is more likely to lead to dehydration and, if the obstruction is at the pylorus, is usually associated with alkalosis inasmuch as the gastric contents which are vomited are usually acid. Unless an associated strangulation is also present, the changes due to dehydration account for most if not all of the systemic manifestations in patients with high intestinal obstruction and often in those with obstruction lower in the gastrointestinal tract (4).

(*b*) The clinical picture of *toxemia* is often seen in intestinal obstruction whenever there is an associated impairment of the blood

supply to the bowel wall. The pathogenesis of these effects of strangulation is not always so clear as that just described in dehydration; nevertheless, it is undoubtedly true that they are due to the absorption of infectious material from the damaged bowel into the circulation. Such absorption is well known in the case of necrotic infected tissue elsewhere. Absorption from strangulated intestine is probably no exception.

Variations in the clinical picture of strangulation are great, dependent, no doubt, upon the degree and rapidity of the absorption. For example, the systemic effects may not be very clear-cut when absorption from the nonviable intestine is gradual; indeed, in such cases, the manifestations may often be scarcely differentiated from those due to dehydration. Much more definite are the systemic effects which follow sudden absorption as, for example, in volvulus of the sigmoid in which a loop of colon becomes completely strangulated, and the toxic transudate produced immediately absorbed through the peritoneum. Such patients are in shock severely prostrated, with a subnormal temperature, fast pulse, and low blood pressure. Although there is, in such cases, both occlusion of the lumen of the gut as well as of the blood supply, the latter occurs so suddenly that the symptoms of shock are produced before dehydration from persistent vomiting and distention have had time to develop.

In an individual case, therefore, the differences may be great due no doubt to variations in the local lesion and in the degree and rapidity of toxic absorption and of dehydration. Nevertheless, with the main outlines in mind it is remarkable how often the systemic effects can be evaluated in terms of pathogenesis.

3. In *paralytic ileus*, as already mentioned, there is no actual mechanical obstruction to the lumen. Although these patients may be distended and dehydrated, other factors, such as peritoneal infection, are responsible for the signs of toxicity often seen. In such cases, the bowel wall itself, in spite of distention, usually maintains a fairly good blood supply in absence of complicating lesions. Six general conditions nearly always precede paralytic ileus: 1. trauma during abdominal operations, which justifies the term postoperative ileus; 2. general peritonitis, usually from a gastrointestinal perforation; 3. skeletal injury, especially to ribs and spine, and retroperitoneal trauma; 4. extraperitoneal infections or toxemia, e.g., pneumonia, nephritis; 5. severe potassium deficiency which often remains uncorrected when water and electrolyte depletions are replaced by sodium chloride alone; and 6. drugs employed for reducing hypertension (such as ansolysin) may lead to abdominal distention of the paralytic type with all radiologic signs thereof. Pain may also be present, leading to a diagnosis of intestinal obstruction.

The fundamental derangement in paralytic ileus is undoubtedly an interference with the nervous mechanism initiating and maintaining peristalsis or a reduction in the capacity of the intestinal musculature to contract adequately. Another factor may be a partial interference in the blood supply following which the affected bowel becomes similarly paralyzed. Regardless of the mechanism, stasis of intestinal content with distention follows with loss of fluid and electrolyte, which is just as pronounced as if there were an actual mechanical barrier in the lumen arresting the passage of bowel contents. Once such stasis has supervened, distention ensues with its train of disturbances and blood chemical changes. The effects of distention in intestinal stasis due to peristaltic failure are just as severe as the distention from stasis produced from actual occlusion of the intestinal lumen.

The gradually developing changes in intestinal obstruction, whatever the cause, might be summarized as follows:

OCCLUSION OF INTESTINAL LUMEN AND/OR EMBARRASSMENT OF INTESTINAL CIRCULATION AND/OR FAILURE OF INTESTINAL PERISTALSIS	STASIS OF INTESTINAL CONTENT	DISTENTION OF INTESTINAL LUMEN	VOMITING DEHYDRATION BLOOD CHEMICAL CHANGES TOXIC ABSORPTION

Clinical Manifestations. The local or abdominal manifestations are described first, then the systemic or general signs and symptoms.

Soon after the intestinal lumen is occluded, regardless of the cause, many primary abdominal symptoms will develop, due to the mechanical occlusion per se. Strangulation often produces, in addition, severe signs and symptoms which are described separately. *Severe intermittent pain of a cramping type* is the most important; it occurs early, is generally located in the epigastrium or around the umbilicus, but may disappear as distention develops. There may be freedom of pain between attacks. Cramps may be especially aggravated by the ingestion of food or cathartics and are often accompanied by hyperperistalsis, audible with or without the stethoscope; this is a very important sign of intestinal obstruction (4). Obvious *distention* appears in a day or two and increases gradually. Distention is more prominent the lower the obstruction. The abdomen is tympanitic due to the presence of considerable gas (tympanites). Distention must be distinguished from ascites which produces shifting dullness, from a mass which reveals itself by careful palpation, and from a distended bladder which disappears after catheterization. Occasionally, the distended loops can be outlined as an intestinal pattern through the abdominal wall of thin individuals. On the other hand, it is often remarkable how much actual distension of the intestines may be present without much external evidence thereof, particularly in robust hyperesthetic individuals with thick abdominal muscles and in the obese. *Vomiting* is more common in high than in low obstruction. An early symptom, it is intermittent, usually follows eating or drinking and is practically or nearly *always preceded by pain*. The amount of vomiting varies greatly, and is usually inversely proportional to the degree of distention. Its character may indicate the site of the obstruction, e.g., clear fluid points to the pylorus; bile stained contents place the occlusion beyond this point; fecal-like vomitus usually originates from the ileum or below. Absence of bowel movements, while common in intestinal obstruction, is not necessarily pathognomonic thereof since it is possible to have bowel movements from retained feces below the obstruction or from a small amount of fecal material which has passed through a barrier not completely occluding the lumen. Another important sign is visible peristalsis which is especially observable in patients with thin abdominal walls, the waves being coincident with the cramping pain and with audible sounds apparent on auscultation. In infants with hypertrophic pyloric stenosis peristaltic waves crossing from left to right can often be seen in the upper abdomen. Palpation is usually negative unless a large tumor is causing the obstruction. In strangulation, a tender mass or localized tenderness may be present. Incarcerated external hernias can be felt except that a small part of the intestine may be strangulated in the femoral or inguinal ring without being apparent externally. Internal herniations are likewise not palpable externally but are rare. Abdominal tenderness is, in general, absent except for localized tenderness over strangulated bowel; there may be diffuse tenderness in the paralytic ileus of general peritonitis. Muscle spasm is rarely present except in the presence of peritonitis (from perforation) or occasionally in strangulation.

A *radiograph* of the abdomen (scout film) is of considerable importance in the diagnosis of intestinal obstruction. In the supine position, the film may reveal the position and contour of dilated loops of bowel. In this way it is usually possible to distinguish dilated small bowel by the characteristic herringbone or "accordion" pattern due to the valvulae conniventi from dilated large bowel which merely shows occasional haustrations. An upright film may reveal the so-called "step ladder" effect or multiple fluid levels. Positive x-ray findings may be seen quite early in small bowel obstruction. When there is an associated strangulation the gas shadows may not be easily found early; frequently the appearance of a small pocket of trapped gas suggests closed loop obstruction associated with volvulus and indicates the position of the obstructed loop. When the distention is due to ascites, x-ray will be valuable in excluding intestinal obstruction because no distended bowel will be seen. A barium enema is of considerable value in that it may reveal the site of or exclude obstruction of the large bowel. In high obstruction, barium by mouth

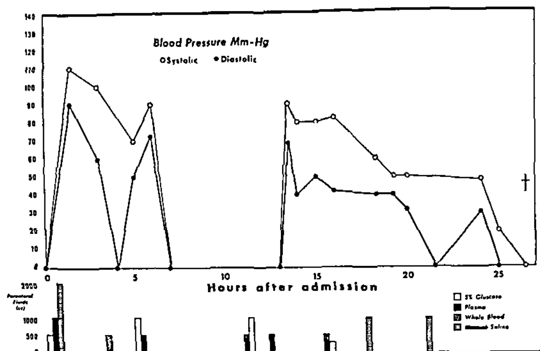


Fig. 4. Surgical shock in intestinal strangulation (volvulus). The patient was a 45-year-old female who died before a diagnosis could be made and who at autopsy showed a large loop of strangulated and gangrenous small intestine. Note the transient response of the blood pressure to intravenous injections. Inasmuch as the fluid lost in the intestine and peritoneum was adequately replaced, the fatal circulatory collapse was clearly due to "toxic" absorption from the damaged bowel. (From the Homer G. Phillips Hospital.)

may be advisable in order to reveal the mechanism or completeness of the occlusion, especially when it develops soon after a gastroenterostomy. However, barium as a routine *should not* be given by mouth in obstruction beyond the pylorus or in any case in which its removal is not assured, because of the danger of increasing the obstruction. This danger is due to the absorption of water from the barium suspension, leaving a hard, insoluble mass which acts as an enterolith. Occasionally, however, under the direct supervision and advice of a trained radiologist, a small barium meal may be so useful in diagnosis as to justify its hazard.

The *systemic manifestations* in intestinal obstruction have already been discussed in part, under pathology. In simple mechanical occlusion of two or three days' duration, such symptoms may be surprisingly absent. If vomiting is profuse, the picture of dehydration gradually develops as already described. Occasionally systemic effects may be absent even though the distended bowel has developed necrosis. This is due to the fact that absorption from the nonviable tissue is prevented by the poor blood flow accompanying the distention. In such a situation general symptoms and signs of a profound infection (fast, bounding pulse, restlessness, and high fever) may rapidly follow *sudden release of distention*. This remarkable occurrence is explained (Fig. 4) by the absorption of toxic material suddenly accelerated by the resumption of blood flow in the bowel wall due to the fall of intraintestinal pressure or release of the strangulating agent. This undoubtedly accounts for the occasional fall of blood pressure and tachycardia which is seen during operation when the neck of the sac in a strangulated hernia is cut, or in the postoperative fever which regularly follows reduction of intussusception.

Intestinal strangulation, when it develops gradually, often but not always produces much more severe local as well as systemic manifestations than does a simple occlusion. In general, *strangulation should be suspected*

when the patient becomes more prostrated, the pulse is rapid, the temperature subnormal, and evidence of circulatory shock is shown by a low blood pressure, cold extremities, and pale cyanotic skin. Pain is usually much more severe, and is more constant. Local tenderness is increased, usually over the site of strangulation. A mass may be palpable. A variable amount of muscle spasm develops. Extremely important in patients with simple mechanical obstruction is the fact that damage to the bowel wall may develop *at any time* during the course of the disease; indeed, occlusion of the lumen and of the blood supply may develop simultaneously. When these "toxic" symptoms develop in simple mechanical occlusion the cause, as already described, is probably the same as that occurring in cases of strangulation. Intestinal strangulation, when seen early as a primary disease, can often be differentiated from mechanical obstruction by the severity of the pain, which may be so intense as to induce complete prostration, though not necessarily shock. Prompt recognition of sudden strangulation is obviously important because of the need for early operation, as discussed below.

Laboratory study in any type of intestinal obstruction will show changes indicative of dehydration, but only when much fluid has been lost by vomiting or into distended bowel without adequate replacement. The urine will also be concentrated and scanty and is a fairly reliable clinical indication of the severity of the dehydration. The leukocyte count may be of differential value for it is usually normal in simple mechanical occlusion, whereas it may be elevated in the presence of strangulation even early in the process. A fall in plasma volume, due to loss of plasma into the affected bowel, has been observed in distention from intestinal obstruction. This change is not amenable to routine clinical measurement but its effect can be detected and, in fact, followed by observing progressive increases in the red cell count (hemoconcentration) and diminutions in the concentration of serum protein (hypoproteinemia).

Differential Diagnosis. The many diseases which simulate intestinal obstruction have been discussed previously and are important in the differential diagnosis of acute abdominal disease. As just mentioned, however, the surgeon must not only determine if intestinal obstruction is present but also must distinguish between functional and mechanical obstruction; of urgent importance is the decision as to whether or not the intestine is strangulated.

In the diagnosis of intestinal obstruction, the detection of an obvious cause is helpful. An incarcerated hernia, an abdominal scar from a previous operation, or an abdominal mass is obviously significant. *Cramping* intermittent pain followed by vomitus containing intestinal contents is especially significant. The x-ray is useful (Figs. 5, 6). Of greatest importance in diagnosis is the prompt detection of strangulation which demands immediate laparotomy.

In *paralytic ileus* the abdominal signs are distention, vomiting, and absence of bowel movements. Pain is frequently absent except in general peritonitis and postoperative ileus. In the latter case, the symptoms are usually transient and described as gas pains. It is important to emphasize that if pain is persistent or develops many days (a week or more) after operation, organic obstruction should be suspected. Tenderness is diffuse and more marked if peritonitis is present; rarely is muscle spasm encountered except in the presence of peritonitis or occasionally strangulation. The causes of paralytic ileus are usually obvious and nearly always permit the surgeon to make such a diagnosis or exclude it as a possible cause of the clinical manifestations.

Treatment of Acute Intestinal Obstruction. Treatment is primarily and *often urgently* surgical but depends first upon the type of disease present. To answer this question, the surgeon must first of all determine whether the clinical manifestations are due to paralytic ileus or to an actual organic occlusion and, if the lesion is organic, whether strangulation is present or not. Strangulation demands immediate operation. On the other hand, paralytic ileus seldom requires operation. In the case of mechanical obstruction, surgery is indicated, but evacuation of the stomach is first performed before the anesthetic is started, thus making anesthesia safer. Moreover, certain types of obstruction (primarily those due to adhesions) are cleared up temporarily by decompression of

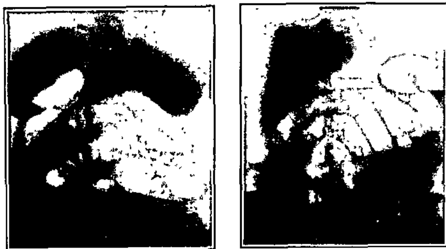


Fig. 5. Roentgenograms showing dilated small intestines. In both films the multiple transverse shadows across the dilated loops are clearly seen; they are called by such terms as herringbone or accordion pattern. The film on the right was taken in the upright position and shows multiple fluid levels as well. Note the similarity in the two pictures even though the lesions found at operation were entirely different. The one on the left was of a 26-year-old woman; distension was due to a simple mechanical obstruction of the terminal ileum from a fibrous band. The one on the right was from a 50-year-old man whose distension was due to a paralytic ileus from a general peritonitis following perforation of an acute appendicitis. In general peritonitis, dilatation of the large bowel (of which only the cecum and part of the ascending colon is visible in this case) constitutes the main roentgenological differentiation from simple mechanical small bowel obstruction.

the upper gastrointestinal tract (1, 5) as is discussed later in detail.

In the following discussion, treatment will be divided into three types, prophylactic, nonoperative, and operative.

1. *Prophylaxis.* An ounce of prevention is worth a pound of cure, which in intestinal obstruction concerns both the surgeon and the physician. For the surgeon, gentle and careful operative technic is essential to minimize the tendency toward postoperative adhesions which are a frequent cause of intestinal obstruction. A large percentage of cases follow gynecologic pelvic procedures; operations for perforated appendicitis are also prone to be followed by intestinal obstruction because of the excessive formation of adhesions which are commonly due to severe infection. The use of talcum powder in gloves undoubtedly led to talc granulomas which were responsible for many cases of postoperative intestinal obstruction. This hazard for the most part has now been removed by the use of soluble powders to aid in donning rubber gloves.

The physician can lower the incidence of intestinal obstruction by recommending herniotomy promptly in patients with reducible hernias, many of whom suffer the inconvenience of trusses for years. In infants and children too, hernia repair soon after the diagnosis is made will eliminate the possibility of strangulation and its high mortality.

Both surgeons and physicians can reduce the seriousness of intestinal obstruction by withholding and indeed condemning the use of catharsis and of morphine in patients with suspected intestinal obstruction. Nature often protects the patient when a cathartic is given when obstruction is present because usually the medicine is promptly vomited. If it is retained it whips up a bowel already working hard to force contents through the small opening and, by increasing peristalsis and distention, aggravates the edema which finally makes the obstruction complete. The tendency of physicians to prescribe a cathartic over the telephone except when the diagnosis is known is certainly a reprehensible one. Unfortunately, it is most often the corner drugstore attendant who is guilty of such well-meaning, but potentially dangerous, advice. The hypodermic of morphine does harm more certainly and insidiously when given

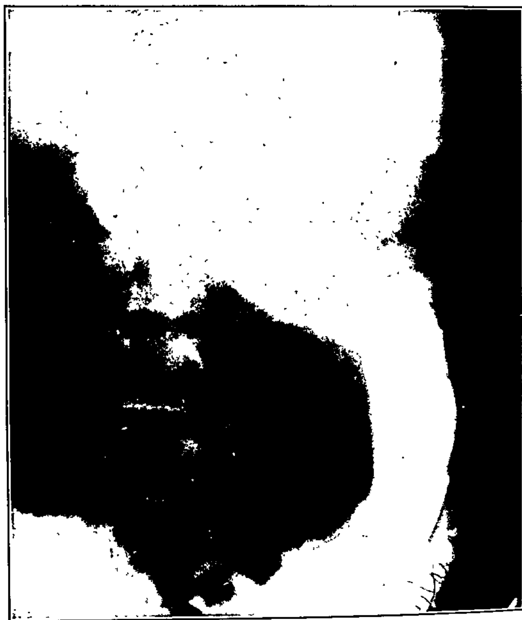


Fig. 6. Acute intestinal obstruction due to carcinoma of the colon. The patient, aged 45, had suffered vague abdominal distress for some months, but for 11 days had been unable to have a bowel movement. The roentgenogram following a barium enema is reproduced above, and shows a complete block at the splenic flexure. At operation a carcinoma was found at this site and was resected, including a portion of the mesentery and a primary anastomosis was carried out. Recovery was uneventful. The patient remained symptom-free for several years but died eventually of distant metastases.

merely to relieve pain. To be sure, it is occasionally useful early in strangulated hernia (i.e., within the first hour or two), because the relaxation induced may allow reduction of the hernia, especially in children; but the patient must be in the hospital and ready for immediate operation if reduction is not effected. The usual circumstance under which it does great harm is its use in the home, often after insufficient examination and certainly after incorrect diagnosis. The danger lies in the fact that the pathologic changes leading to necrosis go on under its apparent beneficent influence. The cramping pain is nature's warning call; the hypodermic stills this call effectively; the patient drops off to sleep and the family is grateful for the seemingly miraculous therapeutic result. But after a short time the patient's pain returns, less severe now, less insistent, but still calling for relief.

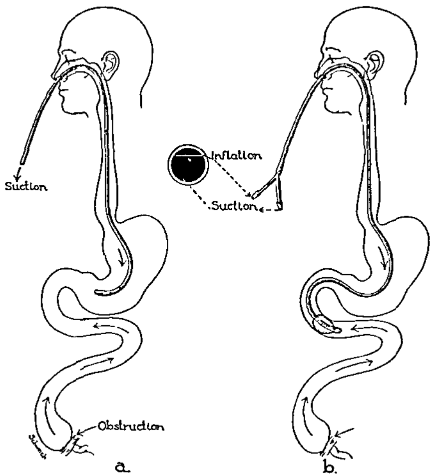


Fig. 7. Gastrointestinal decompression. a, a single lumen long catheter will decompress the stomach and occasionally the duodenum but will rarely enter the jejunum. Only when regurgitation is active can this technic achieve complete deflation; b, the double lumen Miller-Abbott tube, because of the inflatable balloon, once it is in the duodenum, can be carried down to the point of obstruction (provided peristalsis is adequate) and thus achieve complete decompression. In each case mild suction is employed, i.e., the equivalent of a column of water about six feet high. The apparatus must be constantly attended especially to remove plugs of food or mucus which tend to clog the lumen of the tube.

Distention now becomes more marked, dependent somewhat on the amount of fluid ingested and the amount vomited. By now the viability of the intestinal wall has become impaired, setting the stage for a fatal outcome because of absorption of toxic products of bacteria and cellular destruction.

2. *Nonoperative Treatment.* Although the treatment of intestinal obstruction is primarily surgical, a number of nonoperative procedures are important, particularly in preparing the patient for operation. These include the replacement of deficits with adequate parenteral fluids and the use of gastrointestinal decompression.

(*a*) In general, *gastrointestinal decompression* is quite effective in relieving the obstruction due to adhesive bands or paralytic ileus; the former may be completely relieved, especially those occurring within a relatively short time after the operation. On the other hand, in obstruction which develops late after operation, the band that is responsible has usually become fibrous and well developed, so that operation is advisable because of the likelihood of recurrence even though the obstruction is relieved temporarily. Under such circumstances, operation can be carried out with very little difficulty or risk. Continuous gastrointestinal decompression is, of course, strongly contraindicated in any patient in which the obstruc-

tion is due to a strangulated hernia, volvulus, or intussusception. However, even in such cases, decompression should be started along with the injection of fluids while the operating room is being prepared. Such patients will take a much smoother anesthetic with less danger of aspiration if the upper intestinal tract has been partly decompressed even during such a short period as a half hour.

When gastrointestinal suction is indicated, how long shall it be continued before operation must be performed? Too often, indeed, operation is delayed too long. In the consideration of choosing the time for operation certain criteria are important:

(i) The presence or development of intestinal strangulation obviously calls for immediate surgical intervention. This is, of course, immediately evident in a strangulated hernia or in volvulus. Indeed, operation is carried out as an emergency in such cases with no delay for conservative measures except for emptying the stomach and starting intravenous fluids. Much more insidious is the type of vascular obstruction with resulting strangulation which may develop in a patient starting off with a mechanical occlusion of the lumen of the intestine, distention of which may lead to nonviability of the bowel wall. Also insidious is strangulation which becomes superimposed upon a mechanical obstruction because of changes within the abdomen that permit bands to become tighter and occlude the vessels to a loop of intestine not previously involved. Careful study of the patient at frequent intervals usually enables the surgeon to detect even these instances of gradually developing strangulation. The following manifestations are indicative of strangulation: 1. increased pain and local tenderness; 2. increase in the pulse rate; 3. the appearance of either fever or subnormal temperature; 4. increasing leukocytosis; 5. the development of a palpable mass, especially with associated local muscle spasm; and 6. signs of even slight asthenia and prostration. It must be emphasized, however, that the dangers of strangulation are so great the surgeon should err on the side of operating early even if the presence of strangulation is merely suspected.

(ii) Gastrointestinal suction drainage must not be continued if decompression is inadequate and the patient appears to be losing ground. Adequate decompression is shown by the evacuation of considerable gas and fluid from the intestinal tract, cessation of pain, decrease in distention and abdominal tenderness, passage of gas and stool per rectum, and obvious improvement in the patient's general appearance. Several hours may be utilized in trying to achieve adequate decompression in patients who have none of the signs of strangulation as listed above. However, even though signs remain minimal, it is rarely justified to delay operation longer than 24 hours if by that time definite evidence of release (e.g., passage of gas or small amount of stool) has not occurred. If release of obstruction is obtained by decompression, it is very important that it be maintained for at least 48 hours beyond the time when the obstruction has been relieved; if the tube is removed and feedings begun before the lapse of that much time, the obstruction will usually return promptly. Even though decompression may relieve obstruction due to an adhesive band, it is usually advisable to operate later and sever the offending adhesion to prevent another attack, except in obstruction occurring in the immediate postoperative period which, with few exceptions, is relieved by decompression, and permanently. While decompression has been instrumental in saving lives and avoiding the need for operation in many cases, its use when not indicated (intestinal strangulation) or for too long a period has undoubtedly led to needless loss of life. The principle of successful gastrointestinal decompression depends on the fact that relief of distention, in the absence of strangulation, alleviates symptoms, corrects many of the local changes at the obstruction, and permits more adequate study of the patient. Decompression must be used intelligently and the tube must be kept open. The Miller-Abbott tube is designed to pass beyond the duodenum. It has two lumina, one for suction and the other to blow up the balloon on the end of the tube; this balloon acts as a bolus against which the intestine can contract, thus propelling the end of the catheter down the intestinal lumen. However, so much difficulty is experienced with the passage of this tube that it is no longer popular. Many other types of tubes have been devised for

passage into the small bowel. Mercury attached to the end of the tube moves primarily by virtue of its weight and will usually fall to the pylorus if the patient lies on the right side. By distending the stomach with air the same may be accomplished with the ordinary two-lumened tube without mercury. Many directors have been devised to aid in passage of the tube through the pylorus (Abbott, Devine, Smith). If intestinal decompression is to be used, it is best to pass the tube under fluoroscopic control, since otherwise there is loss of valuable time and lack of assurance that the tube is in the small bowel.

(iii) In large bowel obstruction, gastrointestinal decompression is not effective regardless of the cause. In such cases, cecostomy or colostomy is indicated as an emergency operation to relieve the distention and obstruction; if the obstruction is caused by an adhesive band (as it rarely is in large bowel obstruction), the band may be severed; but if a tumor is the cause, as will usually be the case, resection should be postponed for 14 to 18 days after the colostomy to permit adequate decompression and recovery from obstruction.

(*b*) *Parenteral fluids* to correct dehydration are used according to the various methods described in Chapter 9. Three important factors must be emphasized. First of all, the amount must be adequate. It is usually insufficient to give 500 or 1,000 ml. Ordinarily, at least 1,500 to 2,000 ml. must be given to bring the blood volume back to normal. In severely dehydrated patients, as much as 5,000 ml. may have to be given. In the absence of chemical analysis of the blood, one may gain a fair idea of the adequacy of the amount of fluid given by noting the bedside improvement in the patient's clinical picture and the secretion of a dilute urine, indicating that the fluid balance has been restored. Such a result may often be achieved within relatively few hours.

Second, sufficient electrolyte should be included inasmuch as this is an important constituent of the fluid lost by vomiting. Glucose is added because of its advantage as a source of calories, and amino acids as a means of supplying protein food. The correction of dehydration from vomiting with glucose and amino acid solutions alone without electrolyte do more harm than good. While present in the blood stream, the solution is effective in diluting the concentrated blood, but within a few hours the glucose and amino acids are metabolized or stored; the situation then becomes the same as if plain distilled water had been administered. In such a case the body fluids become hypotonic, as shown by a low plasma sodium level. This type of iatrogenic water intoxication calls for the injection of hypertonic (5 per cent) NaCl in amounts of 4 to 7 ml. per kg. of body weight. Dramatic clinical improvement and a good diuresis usually follow. Acute salt deficiency of this kind will not occur often if physiologic saline is used to correct the depletion due to loss of fluids by vomiting. To avoid potassium deficiency, the fluid given should also contain 1 or 2 grams of KCl per liter. To correct a potassium deficiency (as shown for example by persistent paralytic ileus) more must be added, although because of its irritating effect on the vein, one can use only 4 grams of KCl to each liter. In severe cases of potassium deficiency, several days may therefore be required before the intracellular and extracellular potassium levels are restored. Only the latter is revealed by the plasma concentration (see also Chapter 9).

Third, plasma transfusions may be added to replace that lost in obstructed bowel, and to prevent or correct hypoproteinemia especially if the patient has been chronically ill. Indeed, hypoproteinemia may of itself produce nutritional edema of the intestinal mucosa and give rise to signs of intestinal obstruction (Chapter 10). Obviously, if hypoproteinemia is present, the fluid injected intravenously must contain protein; plasma or whole blood transfusions are needed as much as saline and glucose. The existence of much distention should always call for plasma; if the red count is low rather than high, whole blood is preferable.

(*c*) Procedures designed to aid in the passage of obstructed contents from below are of value if successful. Enemas or a rectal tube are used for this purpose. It should be emphasized that the obstructed intestinal contents are nearly always liquid in character; the evacuation of intestinal contents from above the obstruction is indicated by the passage of gas and of liquid stool. This is of particular

importance after the institution of treatment in order to determine if progress is being made in the relief of the obstruction.

(*d*) Removal of fecal impaction, when producing obstruction, is an effective nonoperative treatment which is frequently overlooked, particularly when abdominal distention develops in older and debilitated patients or in children. A rectal examination will nearly always make the diagnosis; manipulation of the fecal mass with the finger aided by oil and small enemas will usually result in relief, particularly if performed in several sessions. Fecal impactions above the rectum probably occur but are difficult if not impossible to establish as a cause of significant obstructive symptoms.

(*e*) Oxygen inhalations are often useful in combating the serious manifestations of strangulation, i.e., "toxic" symptoms, circulatory impairment, and anoxia which may even persist after operative correction. Oxygen is also used to decrease distention.

(*f*) Combined chemotherapy, utilizing penicillin, streptomycin and aureomycin, or terramycin and neomycin, is of tremendous value as an adjunct to surgery, especially in strangulation (3).

3. *Operative Treatment.* Gastrointestinal decompression and other adjunctive procedures are important usually in preoperative preparation (Fig. 7). Even the elimination of gastric distention, which is part of intestinal obstruction, will be advantageous, particularly by minimizing aspiration if operation is done under general anesthesia. When the distention is so slight as not to interfere with surgical intervention, the safest procedure is early operation to correct the cause. Marked distention, on the other hand, always makes operation more hazardous and increases mortality because of the technical difficulties induced. Strangulation, when present, either primarily or as a complication, makes operation imperative as an emergency. However, even in such a case conservative measures, such as suction drainage and parenteral fluids, should be started while the patient is being prepared for operation, which, however, should not be delayed thereby.

Three general operative procedures are available for the relief of acute intestinal ob-

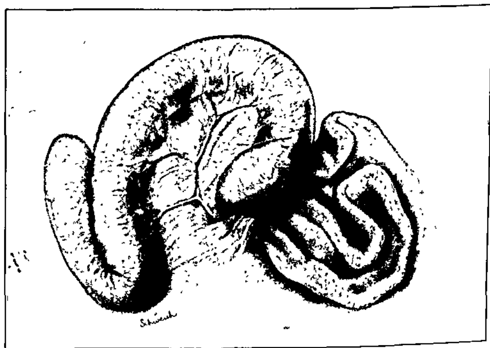


Fig. 8. Acute intestinal obstruction (mechanical occlusion of the lumen). Artist's drawing at time of operation; the dense adhesive band occluded the lumen completely. Note the marked distention of the proximal loop and collapsed distal loop; this obvious contrast was most useful at time of operation in locating the exact site of the occlusion which was corrected by cutting the band. The patient had had a hysterectomy two weeks previously; the pain, distention, vomiting, etc., were, at first, erroneously attributed to postoperative ileus. Recovery was complete.

structions, used either alone or in combination: 1. release of the obstruction; 2. enterostomy; and 3. resection and anastomosis. The details are to be found in works on operative surgery. When there is no evidence of damaged bowel or when relatively little distention is present, the site of the obstruction is located by finding the junction between collapsed and dilated bowel (Fig. 8). The band or bands are cut, or other causes eradicated. Deflation of the obstructed gut will follow correction of the cause. In the very ill patient in whom extensive exploration is unjustified or in whom the obstruction cannot be easily found, operation may be confined to an enterostomy performed under local anesthesia. If intestinal strangulation is present and the involved tissue is definitely nonviable, resection and anastomosis are indicated (Fig. 9). However, if the risk of primary resection and anastomosis is too great, the gangrenous loop may be exteriorized (Mikulicz procedure) before removal, and plastic repair made later. Whether the obstructed or strangulated bowel is viable or not is an obviously important question at the time of operation; the manifestations of viability in strangulation are described on page 845.

In paralytic ileus, operation is indicated only in general peritonitis for eradication of the source of the peritonitis, such as drainage of abscesses and closure of perforations. Although enterostomy has been advised and used in this condition, its efficacy is questionable even in relieving distention, for the drainage is ordinarily successful from only a short

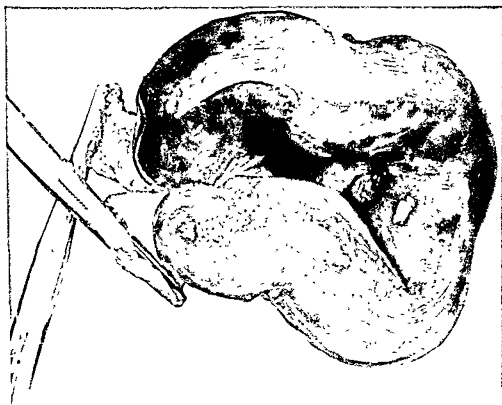


Fig. 9. Intestinal strangulation. Photo of specimen resected in a 35-year-old salesman. Note the gangrene sharply demarcated from normal bowel where the clamps are applied. The cause was a stout band producing this volvulus-type of strangulation The patient was admitted two hours after he was awakened from a sound sleep by agonizing cramping, abdominal pain, nausea, and vomiting. He had had an appendectomy two years before. Examination after admission was essentially negative. The abdomen was scaphoid and showed only slight diffuse tenderness, radiography was negative, laboratory tests all normal. Because of increasing pain he was operated on 10 hours later. A primary end-to-end anastomosis was followed by a relatively uneventful recovery. It is likely that had operation been carried out soon after admission, the band could have been cut and resection made unnecessary.

segment of bowel as long as peristalsis is absent. As soon as the gut becomes active, such drainage is unnecessary since, in absence of organic occlusion, the peristalsis carries intestinal content normally. The use of intestinal decompression is a direct approach to therapy in paralytic ileus, inasmuch as the decompression tube will aspirate back the swallowed air and prevent it from creating distention of the intestine. As the gut is decompressed, activity may be resumed wholly or in part. Ordinarily, however, as mentioned above, paralytic ileus responds to conservative treatment and to measures which correct the primary lesion.

Chronic or Partial Obstruction. Chronic obstruction may be produced by a variety of lesions, including carcinoma of the colon and regional ileitis. There is usually a history of transient attacks of acute obstruction which subside only to recur; occasionally, an erroneous diagnosis of acute appendicitis is made. Often, however, there may be only a progressive and insidiously developing abdominal distention with or without constipation. Besides the lesion causing the partial occlusion of the lumen, the intestine immediately above is thickened, dilated, and hypertrophied. Prompt vomiting and cramps, which follow acute distention of the normal bowel, occur late if at all. It is remarkable that a chronically obstructed small bowel can become so tremendously yet insidiously dilated. Early diagnosis is important not only because cancer may be present, but also because neglect of therapy will lead to progression of the intestinal changes. Radiography is of diagnostic value because the large, dilated, gas-filled loops of intestine show readily on the flat film. The use and danger of using a barium meal has already been mentioned. Treatment is, in general, surgical even if the lesion is benign. In chronic partial obstruction which on most occasions demands operative correction, the major issue will usually be the patient's operability, which will have decreased because of malnutrition, chronic infection, and so forth. If the patient is able to eat a small quantity of food (perhaps 1,000 calories per day), enough may be added intravenously (glucose, amino acids, and fat) and by tube feeding (nasal tube into the stomach) to get the caloric intake up as high as 2,500 or 3,000 calories; if this can be accomplished, it will be desirable to delay operation many days because, by so doing, the operative risk may be reduced from 15 or 20 per cent down to 1 or 2 per cent.

Chronic duodenal ileus represents a clinical syndrome consisting of anorexia, vomiting, and severe loss of weight. It is due to chronic, partial obstruction of the terminal duodenum by the superior mesenteric vessels at the ligament of Treitz as it crosses the bowel at this point. The diagnosis is usually made only by x-ray examination after a barium meal. If the presence of obstruction can be definitely established, surgical treatment is justified. Operation consists of an anastomosis around the occluding band, i.e., duodenojejunostomy.

SPECIFIC LESIONS PRODUCING INTESTINAL OBSTRUCTION

Strangulated Hernia. A common cause of intestinal obstruction is strangulation within a hernial sac; it is so frequent, in fact, that any patient with manifestations of intestinal obstruction should be examined for the possible presence of an inguinal or femoral hernia. The obstruction is nearly always complete. Any loop of intestine may be involved. Operation is, of course, imperative except when normal reduction is possible. A detailed discussion of strangulated hernia will be found on page 844.

Adhesions and Bands. With a few exceptions, adhesions capable of causing intestinal obstruction are produced by a previous abdominal operation, or inflammation, particularly of pelvic origin. Operations commonly producing such adhesions are gynecologic and those performed for perforated appendicitis. The obstruction may develop at almost any time following operation but is, perhaps, encountered most frequently within several months following operation. When true intestinal obstruction develops within the first two or three postoperative days, it is usually due to fresh adhesions associated with the recent operation. It may be difficult to differentiate this from partial rupture of the abdominal wound, with or without the presence of wound infection. Diagnosis may be difficult at this time because postoperative ileus

may produce similar manifestations, including abdominal pain, nausea, vomiting, and distention. Since the adhesions producing obstruction so early after operation are friable and not dense, nonoperative therapy, including decompression, primarily is almost always successful because it relieves edema, which is a prominent feature in the production of the obstruction. If decompression is not successful in yielding partial relief of the obstruction after passage of the tube, emergency operation may be indicated, especially if any of the signs of strangulation as previously discussed are present.

In intestinal obstruction occurring months or years after operation, the adhesive band is more apt to be tough and dense. The adhesion usually connects two peritoneal surfaces and, during the process of contraction, finally becomes tight enough to obstruct the lumen of the bowel, particularly when a secondary inflammation of the intestine and adjacent tissue with edema takes place. The adhesion may produce a necrosis of that portion of the intestinal wall in the area compressed by the band; an entire loop of intestine may be strangulated by a circular band. Obstruction is occasionally produced by attachment of a Meckel's diverticulum to an adjacent point with compression of the underlying loop. Even if the obstruction is relieved by nonoperative therapy, operation should be performed in order to cut the band and prevent the danger of recurrence or of chronic obstruction. The various procedures available for treatment of such patients have been discussed earlier in this chapter.

Neoplasms of the Intestine. With few exceptions, the neoplasms of the intestine capable of producing obstruction are located in the colon and are malignant. The small intestine may, however, become obstructed by attachment to cancer elsewhere or by metastases. Details of the clinical manifestations and treatment will be found where the specific lesions are discussed (Ch. 31).

Intussusception. Invagination of a portion of intestine into an adjacent distal loop (intussusception) is a fairly common type of obstruction; it is rare in adults, and occurs most frequently in infancy and less so with early childhood. This invagination occurs most commonly at the ileocecal valve, but may develop elsewhere in the small and large intestine, particularly in the terminal ileum and upper part of the descending colon (Fig. 10).

In most cases of intussusception, investigation at operation will disclose one or more anatomic features which undoubtedly play an important role in the invagination. An unusually long mesentery of the cecum and ileocecal region will be found most commonly as the only abnormality. In fact, it is doubtful if intussusception can progress far without the existence of this long mesentery. Occasionally, a small Meckel's diverticulum, or a polyp, or a bit of aberrant pancreas is the instigating factor. In any case, occlusion of the vessels of the intussuscepted loop occurs

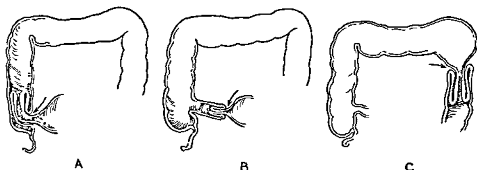


Fig. 10. Three sites for intussusception. The diagrams show only the initial step in the process. In most instances a far longer portion of the ileum or colon becomes involved by the time operation is performed. The arrows indicate the points at which the mesenteric vessels become obstructed by the intussusception. A, at the ileocecal valve; this is by far the most common location. B, at the terminal ileum; intussusception at this site is usually produced by a definite cause, such as an intestinal polyp, a Meckel's diverticulum, and so forth. C, in the descending colon which is exceedingly rare.

segment of bowel as long as peristalsis is absent. As soon as the gut becomes active, such drainage is unnecessary since, in absence of organic occlusion, the peristalsis carries intestinal content normally. The use of intestinal decompression is a direct approach to therapy in paralytic ileus, inasmuch as the decompression tube will aspirate back the swallowed air and prevent it from creating distention of the intestine. As the gut is decompressed, activity may be resumed wholly or in part. Ordinarily, however, as mentioned above, paralytic ileus responds to conservative treatment and to measures which correct the primary lesion.

Chronic or Partial Obstruction. Chronic obstruction may be produced by a variety of lesions, including carcinoma of the colon and *regional ileitis. There is usually a history of* transient attacks of acute obstruction which subside only to recur; occasionally, an erroneous *diagnosis of acute appendicitis* is made. Often, however, there may be only a progressive and insidiously developing abdominal distention with or without constipation. Besides the lesion causing the partial occlusion of the lumen, the intestine immediately above is thickened, dilated, and hypertrophied. Prompt vomiting and cramps, which follow acute distention of the normal bowel, occur late if at all. It is remarkable that a chronically obstructed small bowel can become so tremendously yet insidiously dilated. Early diagnosis is important not only because cancer may be present, but also because neglect of therapy will lead to progression of the intestinal changes. Radiography is of diagnostic value because the large, dilated, gas-filled *loops of intestine show readily on the flat* film. The use and danger of using a barium meal has already been mentioned. Treatment *is, in general, surgical even if the lesion is* benign. In chronic partial obstruction which on most occasions demands operative correc*tion, the major issue will usually be the patient's* operability, which will have decreased because of malnutrition, chronic infection, and so forth. *If the patient is able to eat a* small quantity of food (perhaps 1,000 calories per day), enough may be added intravenously (*glucose, amino acids, and fat*) and by tube feeding (nasal tube into the stomach) to get the caloric intake up as high as 2,500 or 3,000 calories; if this can be accomplished, it will be desirable to *delay operation many* days because, by so doing, the operative risk may be reduced from 15 or 20 per cent down *to 1 or 2 per cent.*

Chronic duodenal ileus represents a clinical syndrome consisting of anorexia, vomiting, and severe loss of weight. It is due to chronic, partial obstruction of the terminal duodenum by the superior mesenteric vessels at the ligament of Treitz as it crosses the bowel at this point. The diagnosis is usually made only by x-ray examination after a barium meal. If the presence of obstruction can be definitely established, surgical treatment is justified. Operation consists of an anastomosis around the occluding band, i.e., duodenojejunostomy.

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particularly because of their tendency to vomit. Parenteral feeding should be continued until there is evidence of a return of gastrointestinal function, as shown by the passage of stool and gas, and by auscultation of peristalsis. Starting with simple liquids, the diet is gradually increased.

The water and electrolyte requirements of infants are often exaggerated during periods of parenteral feeding, as pointed out by Gross (6). The basic water needs of the infant are closer to 75 ml. per kg. than to 150, as often stated. The latter figure is based on the normal oral feeding mixture but is excessive when applied to the sick infant requiring merely maintenance of water balance by parenteral fluids. Excessive salt is even more dangerous, as it is in adults and for the same reasons. To correct deficits, larger intakes are, of course, necessary.

Volvulus. Any free, usually redundant, loop of intestine may become twisted and fixed, thus producing a volvulus (or torsion). Fixation is maintained by adhesive bands but more commonly is due to structural abnormalities. When it occurs in the small intestine, adhesions are very apt to be the inciting factor, or at least the factor responsible for maintenance of the twist. When it occurs in the colon, the sigmoid is a common site for volvulus, apparently because of the long flexure, in which the limbs of the loop are approximated so closely, and because of the long mesentery which exists so frequently at this point. Volvulus of the cecum and ascending colon, though rare, occurs nearly always in children, as a complication of malrotation of intestine, as described later.

Volvulus produces a clinical picture similar to that already described for intestinal obstruction. If the blood supply at the mesentery is completely occluded, severe signs of intestinal strangulation will follow, which may be of dramatic suddenness and accompanied by shock. If the involved loop of intestine is in the colon, it becomes markedly distended with gas and fluid; this distended loop may be so prominent as to be palpable and thus lead to an accurate diagnosis. If strangulation exists, considerable blood-stained fluid may be found in the peritoneal cavity at operation.

On rare occasions, when the volvulus is of short duration and located in the sigmoid, the torsion may be relieved by a barium enema; occasionally, the torsion corrects itself spontaneously and a history of subsiding attacks may be obtained (recurrent volvulus). Occasionally, the obstruction can be relieved by inserting a sigmoidoscope and passing a large catheter up into the involved loop of sigmoid through the obstructed area created by the twist. However, most surgeons do not utilize this procedure; they prefer not to run the risk of failure that would obviously delay correction by operation, which is the only curative procedure. If strangulation is not present, untwisting the loop may be sufficient to entirely relieve the obstruction. Any adhesive bands present should be cut. Since the sigmoid is the area most subject to recurrence of a volvulus, excision of the involved loop may be indicated even if strangulation is not present. Resection with primary anastomosis is usually preferable when the torsion involves the small intestine: in the sigmoid, exteriorization after the Mikulicz procedure, followed by anastomosis later, is usually preferable, but a planned resection and primary anastomosis may be justified when the operation is carried out to prevent recurrent volvulus.

Malrotation of the Intestine. Anomalies of rotation of the intestine during embryonic life may be responsible for a number of different types of intestinal obstruction. Before the mechanisms of these types of obstruction can be understood, it is necessary to be familiar with the main features of intestinal rotation. Normally, the midgut recedes from its position in the yolk sac, through the umbilical orifice, into the abdominal cavity at about the tenth week of embryonic life. The cecum is the last portion of the intestine to enter the abdominal cavity and, from its position in the left posterior portion of the yolk sac, rotates 270 degrees on the axis of the superior mesenteric artery from the left upper quadrant in a counterclockwise direction to its permanent position in the right lower quadrant.

Incomplete rotation of the cecum is the most common anomaly. When this occurs, the cecum and part of the ascending colon with the terminal ileum are found in the upper left quadrant and the terminal ileum is attached to the jejunum with a broad band. This not only prevents return of the cecum

at a variable time after onset. As this vascular compression increases, gangrene of the involved intestine develops, which leads to a fatal outcome unless the necrotic segment is sloughed into the lumen; this occurs but is extremely rare. Adhesions may cause the intussusception and obstruction to persist.

The *clinical manifestations* are remarkably constant and dramatic. One of the first symptoms noted is pain, which is presumably severe, as expressed by irritability of the infant who screams and cries out frequently, holding its abdomen. Shortly after the onset of the pain, nausea and vomiting are noted. Within an hour or two, manifestations of shock, such as listlessness, weakness, prostration, and pallor, develop. The pulse rapidly becomes fast, weak, and thready. There are two features of this shock which appear to be of particular diagnostic significance, namely the dusky color associated with the pallor, and the extreme prostration which develops rapidly following onset. However, these features of shock may also be exhibited in infants with intestinal obstruction produced by other causes. Occasionally, shock of the type just described will be seen without pain (screaming and crying), the mother noting only listlessness, prostration, and pallor. It is not *uncommon for the infant to have a normal bowel movement* shortly after the onset of pain. Following this, other stools will be passed, which at first contain mucus, later mucus streaked with blood, and finally pure blood, the color of which depends upon the location of the intussusception. A mass is usually palpable, first in the right lower quadrant, but moves progressively upward toward the epigastrium and across to the left side of the abdomen with the lapse of time. Muscle spasm and tenderness are rarely severe, if present at all. Peristaltic waves may or may not be visible. *Distention usually occurs but is not* a prominent feature until after 24 hours. *Obstruction is usually complete* soon after onset; an enema yields chiefly mucus and blood. On rare occasions, the intussusception is relieved spontaneously or after an enema; this occurs only early in the disease and is apt to be followed by recurrence. Recurrent intussusception is probably the cause of certain obscure intestinal episodes in infancy. Fever may be present, but usually only in the late stage of the obstruction. Leukocytosis may or may not be present. Rectal examination will reveal bloody mucus in the rectum; the mass may be palpable by the examining finger.

Treatment is surgical and should be *delayed only long* enough to insert a catheter after cutting down on a leg vein for the injection of blood and fluids. This can be done in the operating room if necessary. Ether anesthesia will usually be indicated but very little if any is really needed if the child is in shock, at least in the beginning. Local anesthesia may be adequate. A right paramedian incision should be made if no mass is palpable. However, if a mass is demonstrable, the incision should be made over it. At operation, the intussuscepted loop is reduced most effectively by gentle compression from the distal end. Pulling on the proximal loop is comparatively ineffective when the intussusception has been present for more than a few hours and may produce a tear in the intestine. Reduction may be impossible, usually because of adhesions or gangrene. In this event, resection will be necessary and, in most cases, can be safely followed by primary anastomosis. Excision of the gangrenous mass will be followed by an immediate improvement in the general condition of the infant due to the *removal of the focus of* "toxic absorption." Should the mass be exteriorized for resection, thus creating a double-barreled enterostomy, repair should be carried out as soon as possible, usually in a few days. If manifestations of shock are at all pronounced or persist, a blood transfusion should be given during or immediately after the end of the operation. Oxygen inhalation will also be valuable in such cases. If the general condition is good, it may be advisable to do an appendectomy, which, by laying down scar tends to prevent recurrence. An intussusception, when seen *early and when the mass* is still small, can occasionally be reduced under the fluoroscope by means of a barium enema, which must be carefully given without too much pressure. However, this procedure has its limitations and, in any case, if used should not unduly delay operation which must be immediately carried out if the reduction by enema fails.

Proper postoperative feeding may be of extreme importance in the convalescence of these patients (most of whom are infants),



Fig. 11. Congenital hypertrophic stenosis of the pylorus. The infant was six weeks old. The two photographs were taken a few seconds apart. A, note the peristaltic wave beginning low in the left hypochondrium. In B, it has moved toward the patient's right and downward; the trough of a second wave is also seen approaching the pylorus, above and to the right of the umbilicus. Pyloromyotomy (Fredet-Ramstedt operation) was followed by an uneventful recovery.

of the impacted meconium. Should the obstruction persist, operation is indicated. Some of these cases, unfortunately, are associated with failure of a fibrocystic pancreas to produce adequate proteolytic ferment to dissolve the meconium. At operation, diagnosis is evident by the leathery, narrowed gut containing tough, sticky meconium. If it can be dissolved by the injection of solutions containing proteolytic ferments or hydrogen peroxide, continuity of the lumen may be achieved. Usually, however, it is necessary to resect the involved bowel. Gross (6) prefers resection by the Mikulicz exteriorization technic, closing the ileostomy two or three weeks later; there will be very little irritation of the skin because the intestinal fluids are deficient in enzymes.

Hypertrophic Pyloric Stenosis. This disease occurs in early infancy and is due to a pyloric obstruction produced by hypertrophy of the circular pyloric muscles, although there is probably some degree of associated spasm. The disease is much more common in males than in females. The symptoms first appear at the second or third week of life and consist primarily of vomiting. At first the vomiting may be manifested merely as a regurgitation but later becomes projectile. The child usually vomits after every feeding and frequently the entire feeding. The vomitus never contains bile since the obstruction is proximal to the ampulla of Vater. Unless the child is fed again after vomiting, dehydration and loss of weight may take place rapidly. In spite of refeeding and extreme care in choice of formulas and the use of muscle-relaxing drugs, gradual loss of weight is the rule. Constipation is obviously and always present. Shortly after the onset of the disease peristaltic waves will be observed, beginning characteristically at the left costal margin and passing to the right, particularly after ingesting fluid (Fig. 11). It may be necessary to examine the child several times before significant peristaltic waves are demonstrable. A palpable tumor in the right upper quadrant of the abdomen can often be felt; it is about the size of a small olive and represents the firm area of hypertrophied pyloric muscle. However, palpation of a tumor is not essential for diagnosis. A roentgenogram will reveal merely a large, dilated stomach. Fluoroscopy after a barium meal may be carried out

to its normal position in the right lower quadrant but leads to a twisting or volvulus of the entire small gut. *This obstruction may not* occur for several months or years after birth; manifestations are similar to those of obstruction and volvulus as already described. A history of intermittent attacks of intestinal obstruction may be obtained. Cure may be effected by cutting the band which has produced the obstruction and maintained the malrotated position. Occasionally, rotation takes place in the reversed direction (clockwise). In this case, the positions of the duodenum and colon with respect to the mesenteric artery will be reversed, i.e., the duodenum will be anterior to the superior mesenteric artery and the colon posterior to the artery.

The various features of malrotation of the intestine have been well described by Gross (6). *Even in the absence of volvulus, symp*toms of "chronic" intestinal obstruction may develop because of sharp angulations produced by anomalous attachments, particularly in the terminal portion of the duodenum. A correct diagnosis can seldom be made previous to operation even by means of fluoroscopic and x-ray study with the barium meal. At operation however, the diagnosis is usually evident, provided the entire gastrointestinal tract is eviscerated through a long incision and the true state of affairs accurately determined. Only then can the defect, of which there are many different and bizarre kinds, be detected and remedied.

Congenital Stenosis and Atresia. Complete or partial intestinal obstruction, when evident soon after birth, is usually due to congenital stenosis (narrowing of the lumen), and/or atresia (complete obliteration of the lumen). The former is due to the pressure of a congenital band, the latter to agenesis or undissolved meconium (see below). The various sites and varieties are shown in Fig. 1, p. 819. Atresias or stenoses are most common in the duodenum (third portion), next in the terminal ileum.

The symptoms produced will depend on the site and completeness of the obstruction. Duodenal obstruction will be associated with the vomiting of bile-stained material, unlike the vomitus of clear gastric contents in pyloric stenosis. The x-ray will usually be very helpful in establishing the diagnosis (7). If the obstruction is in the duodenum, the stomach and first part of the duodenum will show gaseous distention but no gas in the rest of the gastrointestinal tract. If the obstruction is located in the terminal ileum, the entire small bowel will be distended. When the obstruction is partial or intermittent, the infant may not be seen until later in life, since normal growth will occur between attacks.

Operation will be indicated immediately in the case of a complete atresia (8) and later in the case of partial or incomplete obstruction, which is serious enough to produce symptoms and/or to disturb the child's growth and nutrition. Newborn babies, even when premature, withstand operation surprisingly well (9) if the obstruction is relieved. Complete exposure is necessary. The introduction of a tiny plastic tube into the stomach, passed into the duodenum, and inflated or injected with fluid often helps in differentiation between atresia and stenosis, since congenital bands are sometimes present with atresia due to a diaphragm. Correction of the obstruction is, of course, a primary necessity and can usually be carried out in every instance, even if an anastomosis is needed. Fine arterial needles and silk are helpful. The most readily and easily corrected types are those caused by a congenital band, which is simply severed. Congenital lesions (e.g., multiple areas of stenosis) sometimes require resection of a considerable length of ileum or jejunum which are tolerated quite well by infants (10) —if they survive the immediate effects of the operation—but removal of long segments may be followed by gastrointestinal disturbances with limitations on growth. Imperforate anus, another type of atresia requiring operation, is discussed on page 777. For details of these and allied lesions of infancy and childhood see the texts by Gross (6) and Swenson (11).

Meconium Ileus. This is a rare but often serious condition occurring immediately or soon after birth. Inspissated undissolved meconium may remain in parts of the lumen of the terminal ileum and colon, producing all of the signs of intestinal obstruction with increasing abdominal distention, nausea, and vomiting. Fortunately, such symptoms are sometimes transient and cease on evacuation

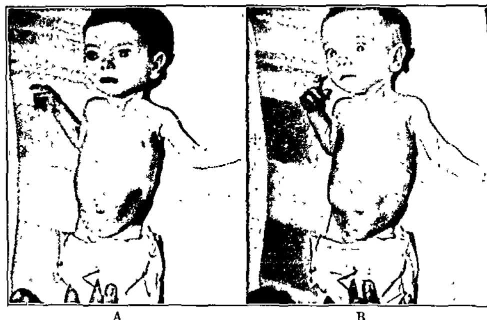


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and will indicate the degree and completeness of the pyloric obstruction; however, if barium is given, the part remaining in the stomach must be evacuated by a nasal tube when the roentgen examination is completed.

The *treatment* is primarily surgical, but it is of extreme importance that operation be performed only after water, electrolyte, and other deficiencies are corrected; the parenteral route must be used and consists of hypodermoclysis of 200 to 250 ml. isotonic saline solution or Ringer's solution; intravenous administration of 20 ml. of 10 per cent glucose per kg. of body weight, once or twice daily, plus amino acids, may also be advisable. The alkalosis will nearly always be corrected by the giving of physiologic saline. In advanced cases, however, acidic (ammonium chloride) salts may have to be used. If potassium deficiency is associated, this salt should be added. Excessive parenteral fluid administration must be avoided, as already mentioned. If the infant is in especially poor condition a transfusion of 15 to 20 ml. of blood per kg. of body weight may be advisable. Because infants with pyloric stenosis are prone to acquire infections of various types, frequent examinations must be carried out to detect their existence, especially if fever is present. Such infections in themselves are apt to produce vomiting. Proper therapy, including chemotherapy, will be effective in the cessation or diminution of vomiting.

Pyloromyotomy, known as the Fredet-Ramstedt operation, first described in 1912, is curative if properly performed. It consists of division of the dense, firm, hypertrophied, circular muscle fibers at the most bloodless point on the pylorus. Separation is continued until all fibers are broken and the submucosa pouts out into the wound in the pylorus. Extreme care must be taken not to perforate the submucosa; if unrecognized or inadequately repaired, it will lead to a fatal peritonitis. This accident is most apt to occur at the duodenal end; if it occurs, the opening is repaired by one or two interrupted silk sutures taken in a diagonal longitudinal direction. Anchorage of a tag of omentum over the opening will also be of value. Local or general anesthesia may be used. The former should be supplemented with a preliminary sedative. Preoperative gastric lavage appears to increase the toleration for postoperative feeding.

Postoperative care should not be left to chance, especially in regard to feeding. The tendency to force feeding in too large quantities during the first few days is harmful because the stomach is frequently unable to fully empty itself because of gastric atony due to the previous and often long period of pyloric obstruction. Normal gastric peristalsis in such infants is regained only after 24 to 72 hours following pyloromyotomy. During this period, overdistention must be avoided. Half an ounce of water may be offered as early as two hours after operation, but it is probably better to wait 12 hours. Thereafter, the feedings should be dilute at first and limited to 15 ml. per feeding. A mixture of 30 ml. evaporated milk, 30 ml. of 10 per cent buffered solution, 30 ml. of water, and 4 grams of dextrimaltose is made up; this allows administration of six feedings of 15 ml. each. The individual feedings are gradually increased as tolerated. As a routine the amount may be increased 15 ml. each day so that the infant gets six feedings of 30 ml. on the second day, 45 ml. on the third day, and so on until a normal requirement of about 120 ml. is met. After several days the feeding should be concentrated slightly by prescribing a formula of two parts evaporated milk, two parts 1 per cent lactic acid, and one part water; sufficient dextrimaltose is added to make a 6 per cent solution. Before the child is discharged from the hospital, the feeding should be concentrated still more to that of a normal intake, i.e., equal parts of evaporated milk and water to which sufficient dextrimaltose syrup is added to make a 6 per cent solution.

If vomiting continues after operation it does not necessarily mean that the pyloromyotomy was inadequate and needs to be redone. Vomiting may sometimes be diminished or eradicated by sedation, such as one eighth grain phenobarbital every four hours, or, better still, by reducing the amount of feeding for reasons already mentioned. Gastric atony may also be combated by emptying the stomach once or twice every 24 hours for the first few days; favorable progress is indicated by the fact that the amount removed is progressively less than the amount ingested.

Electrolyte and especially potassium deficiency as well as protein depletion may play a part and demand correction. Occasionally, the vomiting is due to extraalimentary infection or other factors not connected with the operation, as mentioned above. A second operation is rarely necessary.

Miscellaneous Lesions Producing Obstruction. There are numerous miscellaneous lesions which are capable of producing either partial or complete obstruction; most of these are discussed in detail elsewhere. Not uncommonly, the amount of inflammation occurring with a *diverticulitis* of the colon will be sufficient to produce severe obstructive symptoms. *Stricture* formation (noncongenital) may occur in any part of the alimentary tract and may be sufficiently severe to produce a total obstruction. In the upper part of the digestive tract, it occurs most often in the esophagus and pylorus. Strangulation is rarely produced by this type of obstruction, although dehydration from loss of fluid through vomiting may produce severe systemic manifestations, particularly in pyloric obstruction. Detailed descriptions will be found elsewhere. Stricture of the rectum due to lymphogranuloma venereum rarely results in acute obstruction (see Chap. 7). Occasionally *benign ulceration* of the intestine, produced by amebiasis, tuberculosis, and so forth, will result in a stricture; these lesions are usually located in the colon. Confirmatory evidence of obstruction will be noted by x-ray, but a diagnosis of carcinoma will usually be made. Operative correction will obviously be indicated in



Fig. 12. Mesenteric thrombosis. Photomicrographs from a section of the excised intestine, showing obstructed vessels. A, is a thrombosed vessel in the intestinal wall and B, an occluded artery and vein in the mesentery. Note also the surrounding edema in A. The thrombosis in the mesenteric vein is obviously of longer duration than that in its accompanying artery. The patient was a 37-year-old housewife; two weeks previously she had been delivered of a normal infant and was enjoying a normal puerperium, when, two days before admission she was suddenly seized with generalized abdominal cramps which became severe and were accompanied by persistent vomiting; blood was noted in the stool Prostration became quite pronounced. At operation, two and one-half feet of nonviable intestine was resected and a primary anastomosis performed; followed by a lateral anastomosis; recovery was uneventful.

most instances. Two types of operative procedures are available: 1. an anastomosis around the stricture can be performed; or 2. the mass can be resected. However, as stated previously, resection of a colonic tumor (with primary anastomosis) is rarely performed in the presence of complete obstruction, because of the high mortality rate. Usually, the obstruction is relieved by a colostomy, and the resection done two weeks later. Regional ileitis often produces signs of intestinal obstruction and is described on page 745.

Mesenteric thrombosis produces nearly all the manifestations of a complete obstruction because of the paralysis of the peristaltic mechanism in the involved area (Fig. 12). More important is the effect of the thrombosis on the viability of the affected intestine, inasmuch as acute sudden manifestations, as described for intestinal strangulation, are produced thereby. The obliteration of the vessels may be due primarily to an embolus or thrombosis. The disease is encountered in patients afflicted with endocarditis, vascular disease, and the like, but frequently develops in supposedly healthy people in whom no etiologic factor can be found. The effects are similar, in general, to those produced by intestinal strangulation, which has already been described (p. 825). Pain is severe, diffuse, and constant; even large doses of morphine are often ineffective in relieving it. Nausea and vomiting are also present. Characteristic is the prostration and shock which rapidly develop; pallor, cyanosis, and low blood pressure with rapid, thready pulse may be noted.

Mesenteric thrombosis involving the colon may produce shock more rapidly but certainly not always. Examination of the abdomen reveals diffuse tenderness and muscle spasm. A tubular mass representing the involved intestine may be palpable. There is usually a marked leukocytosis. If a stool is passed, gross blood may be noted which is of considerable diagnostic importance. Often mesenteric thrombosis is first recognized at operation. If the bowel is gangrenous, resection or exteriorization is obviously indicated. If resection is necessary, prognosis may be more serious because more bacteria are present in the colon.

Intestinal obstruction due to *enteroliths* is rare but most commonly is produced by the ulceration of a large gallstone through the wall of the gallbladder into the duodenum with lodgment in the ileum (gallstone ileus), where it may be discernible in an x-ray film. Usually the diagnosis is first made at operation, during which the stone is removed and the opening in the intestine closed. Fecal impaction occurs frequently but only rarely produces manifestations of acute obstruction.

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34

HERNIA

General Considerations
Specific Types of Hernia

GENERAL CONSIDERATIONS

Definitions. Any protrusion of tissue through an abnormal opening in the wall of a body cavity, particularly the abdomen (including an abnormal hiatus in omentum or mesentery) may be called a *hernia*. Through this opening, such organs as intestine, omentum, and so forth, may pass. Most hernias are *reducible;* their contents can be replaced by manipulation into the cavity of origin or may recede spontaneously when the patient lies down. When the mass cannot be reduced, the hernia is spoken of as *irreducible*. There is a time factor in the term irreducible, for many hernias are irreducible at times and reducible at others. When the hernia becomes permanently irreducible, the term *incarcerated* is used (despite some difference of opinion). An *obstructed hernia* is one containing intestine whose lumen becomes blocked by adhesions, angulation, volvulus, fecal impaction, and the like. Some authorities consider incarceration synonymous with irreducibility, whereas others use the term synonymously with obstructed hernia. Occasionally, only a portion of the intestinal wall is caught in a small hernial opening without obstructing the lumen of the intestine, thereby constituting what is called *Richter's hernia*. This type of hernia occurs most frequently in femoral and inguinal hernias. A *strangulated hernia* is one containing viscera whose blood supply is partially or completely blocked. In such an instance, gangrene obviously follows, unless the block is relieved within a few hours. The terms *true* and *false hernia* are sometimes used to differentiate between hernias having sacs (true hernias) and those not having sacs (false hernias).

Entirely apart from the above terms which really apply to the degree of herniation, hernias are ordinarily classified according to their anatomic location. The most common types are those in the inguinal and femoral region. These and others are described in detail later in the chapter.

Etiologic Factors. The development of most hernias is probably based on the presence of a congenital defect, such as a structural weakness of the supporting structures at the point of herniation, to an unobliterated embryologic channel or process. Despite a definite history of sudden pain in the groin associated with the appearance of a hernial mass immediately following severe strain, such as lifting, it seems probable that the strain was merely the precipitating factor. However, it should be stated that compensation boards usually consider trauma as being capable of producing hernias and rarely fail to return a verdict in favor of the workman who merely states that the hernia appeared during work.

Hernia may first appear at any time during life, but an analysis by Watson (1) indicates that 15 per cent occur during the first year. Obesity, pregnancy, and other conditions which predispose to relaxation and disuse of certain muscles are important secondary causes. In elderly men with prostatic obstruction, the straining incident to difficulty with urination is at times an apparent factor in the development of inguinal hernias, particularly the direct type. A more detailed discussion will be found in the book by Iason (2).

General Clinical Manifestations. A hernia is usually noticed because of the appearance

of a protrusion or mass and is nearly always accompanied by a moderate amount of pain during the first few days. It may or may not be preceded by a history of physical exertion. The pain decreases so that after two or three weeks the symptoms complained of consist of nothing more than a mild feeling of discomfort. There is a tendency for the protruding mass to increase in size. Most hernias are reducible, especially when they are of recent origin. The recumbent position facilitates reduction. After reduction of the mass one can usually feel the defect through which the hernia has protruded. Many hernias become irreducible, especially when the patient has been wearing an ineffective truss or other appliance, because of the adhesions produced between the sac and its contents. The mass is soft, semifluctuant, and usually not tender. In contrast to hydrocele (see p. 1152), it rarely transmits light. The surface is usually not so smooth or regular as that of hydrocele. If intestine is included in the contents of the hernia, percussion will usually reveal a tympanitic note. One of the most reliable diagnostic features of hernia is the impulse transmitted to and enlargement of the mass when the patient coughs. If a hernia is present but no mass presents, coughing will result in a protrusion which can be palpated by the finger placed in the hernial opening or inguinal canal.

Frequently a patient presents himself with the history of having been examined by an industrial doctor who has found a dilated external ring with an impulse on coughing and has advised surgical treatment before employment will be recommended. Though an actual protrusion is not always demonstrable in these cases, operation may be indicated. On many such occasions a small empty sac will be found. Such an empty sac can sometimes be felt along the cord by exerting slight traction on the testicle.

Pronounced and serious symptoms of hernia are produced when the contents become obstructed and strangulated. This, in itself, is such a serious complication that it is considered first.

Obstructed Hernia. Years ago, obstruction in a hernia constituted the most common type of intestinal obstruction. However, the increasing incidence of intraabdominal operations (with resultant obstruction due to adhesions) and the increasing incidence of cancer of the gastrointestinal tract have reduced the percentage due to hernias. In a study of 1,252 cases of intestinal obstruction, Smith and associates (3) found that hernia was the cause in 10.2 per cent, ranking third. However, in their series, hernia was the most common cause of strangulation.

The manifestations of obstruction due to hernia are similar to those of other types, consisting primarily of cramping pain, nausea, vomiting, and obstipation (see Ch. 33). It must be emphasized, however, that the local findings may be so minimal in about half the cases as to confuse the clinician. The presence of an irreducible mass (hernia), cramping pain, nausea, and vomiting, constitute indications for operation until proved otherwise. The over-all operative mortality rate in 130 patients with obstruction due to hernia treated by Smith and associates (4) was 6.9 per cent.

Strangulated Hernia. The term strangulated hernia is frequently applied erroneously to obstructed hernias. With few exceptions, strangulation does not develop until several hours after the hernia becomes obstructed (Fig. 1). Only in Richter's hernia does strangulation occur in the absence of obstruction. Obstruction, and particularly strangulation, are most prone to develop when the ring (e.g., external inguinal) through which the hernia protrudes, is small. The mechanism of strangulation consists first of compression of the veins, followed by edema, later by arterial compression, and gangrene.

When strangulation develops, symptoms are more acute (see Ch. 33). Tension within the mass increases, and there is less tendency to reducibility. Nausea and vomiting become more pronounced. The pain increases and is so persistent that the patient seeks medical attention early. This pain at first is poorly localized, but soon becomes most prominent in the mass, radiating frequently into the depth of the abdomen. The temperature is normal or subnormal, but later becomes elevated. Tachycardia develops early. Occasionally, the patient exhibits mild collapse with a cold, pale, and moist skin, especially if a large amount of intestine is involved in the strangulation. This may be caused in part by



Fig. 1. Gangrenous loop of small intestine removed from a strangulated hernia. The hernia had been present *almost asymptomatically for a great many years. About 12 hours before admission the patient*, aged 45, suddenly experienced severe abdominal pain, nausea and vomiting, and found that the hernia was irreducible. Marked prostration developed. At operation the entire loop of intestine constricted by the hernial sac was gangrenous; it was resected and a lateral anastomosis performed. The arrows indicate the points of constriction.

the large amount of blood and plasma which may become trapped in the obstructed area. Another explanation of shock is the absorption, usually transperitoneally, of toxic substances from the gangrenous intestine. Other manifestations of intestinal obstruction alone, including distention and tympanites, gradually develop (see Chap. 33). Enemas are ineffectual. The mass itself, if palpable, is usually *moderately tense and tender*. By percussion and transillumination of light, it may be possible to demonstrate the presence of both fluid and gas in the sac. The skin itself may become discolored but usually only after the strangulation and gangrene have been present for a long time. Spasm of abdominal muscles will be present if the hernia is intraabdominal; if the hernia is scrotal, moderate spasm with pain may be noted in the lower abdomen. It must be emphasized, however, that in certain cases, manifestations are so mild that it is difficult to differentiate a strangulated from a nonstrangulated (obstructed) hernia.

On rare occasions, strangulation may occur in an internal hernia and there will obviously be no demonstrable external herniation to account for the symptoms. In such instances, the patient is usually operated on for intestinal obstruction, and the actual strangulation is not discovered until the time of operation. When the strangulated tissue consists solely of omentum, the pain is usually much less severe and vomiting frequently absent. The degree of tachycardia and prostration are likewise less prominent. Although strangulation of omentum is obviously followed by gangrene, this condition is not as serious as strangulated intestine. Occasionally, the necrotic omentum becomes infected, which may eventually form an abscess and burrow through the skin.

The *treatment* of strangulation is emergency operation. If the acute incarceration is *recent* (i.e., of only two or three hours' duration), gentle efforts at reduction may be attempted after giving a narcotic or placing the patient in a hot bath. However, such manipulation must be *gentle* and performed with

judgment, lest strangulated bowel be injured or reduced en masse; if perforation results under such circumstances, it can only be because all the principles learned in medicine about gentleness in handling of tissues has been disregarded. If possible, operation should be performed under local anesthesia because these patients do not tolerate general anesthesia well. When the hernial sac is opened, a moderate amount of blood-stained fluid will usually be found within it, regardless of whether or not the contents consist of intestine or omentum. If the intestine is involved in the strangulation, color changes will be noted. In the early cases, the intestine may be merely reddened or slightly cyanosed and the glistening luster of the serosa will be unchanged. In later cases, the luster of the serosa will be lost, and the cyanosis will have progressed to a black color indicating that the intestine is no longer viable, and resection is necessary. The viability of the intestines is determined to a great extent by the presence or absence of the glistening appearance of the serosa. If this is lost and is not regained after release of the obstruction, and application of warm wet packs for five minutes, it is usually considered unsafe to replace the affected portion of intestine. Resection of this gangrenous loop may be performed in one of several ways. With few exceptions, resection with primary anastomosis is indicated.

SPECIFIC TYPES OF HERNIA

Inguinal Hernia. Hernias of this type may be either direct or indirect, but they can be more clearly discussed if the *anatomic* features of the *inguinal canal* are understood. This canal is an oblique passage about 4 cm. long in the male, passing downward and medially from the abdominal (internal) to the subcutaneous (external) ring and is situated parallel to, and above, Poupart's ligament. In the male, it transmits the spermatic cord and vessels, the ilioinguinal nerve and a branch of the genitocrural nerve; in the female, the round ligament and the two nerves just mentioned. The roof of the canal consists primarily of the aponeurosis of the external oblique, and at the upper third, the fibers of the internal oblique. The posterior wall consists largely of the transversalis fascia. Poupart's ligament forms the lateral wall, and the arched fibers of the internal oblique and transversalis muscle form the medial wall. The conjoined tendon is an important structure, particularly because its aponeurotic structure is useful in repair. It is a broad fascial band consisting of the union of the internal oblique, transversalis fascia and the anterior rectus sheath; it is attached to the tubercle of the symphysis pubis. The subcutaneous ring lies between the terminal portions of the conjoined tendon and Poupart's ligament; it varies normally in size from a slit barely large enough to admit the tip of the finger to a circular opening into which one or two fingers can be inserted. The abdominal ring cannot be palpated but can be occluded by pressure over it. The deep epigastric artery passes from its point of origin from the external iliac artery in the floor of the pelvis upward and inward toward the umbilicus from a point midway between the anterior superior spine and symphysis pubis. It lies between the peritoneum and abdominal muscles and is a landmark which determines (at operation) whether a hernia is direct or indirect; if the artery is lateral to the neck of the sac, the hernia is direct; if medial to the neck, the hernia is indirect.

INDIRECT (OBLIQUE) INGUINAL HERNIA. Hernias of this type in particular are due to a congenital patency of the upper end of the processus vaginalis, into which the indirect hernia makes its entrance into the inguinal canal (Fig. 2). This may be clarified by briefly reviewing the mechanism of the descent of the testicle. As the testicle descends from its embryonic retroperitoneal position, it carries peritoneum along with it through the inguinal canal and into the scrotum. This potential sac is called the *processus vaginalis* and some time before birth becomes obliterated through its entire extent, except the part which surrounds the testicle. This portion is normally not obliterated and remains as a closed potential cavity known as the *tunica vaginalis*. The part of the processus vaginalis which extends along the cord is called the funicular process. Normally, the funicular process closes throughout its extent, but if this mechanism fails to take place before birth, there will be a direct communication from the peritoneal cavity down to the testicle.

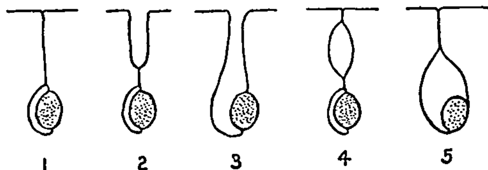


Fig. 2. Relation of the processus vaginalis to the more common types of hydrocele and hernias. 1, normal obliteration of the funicular process; the distal end of the vaginal process remains at the tunica vaginalis. 2, funicular hernia caused by the patency of the proximal portion of the process. 3, complete patency of the process, resulting in the formation of a testicular hernia. 4, hydrocele of the cord produced by patency of the central portion (and accumulation of fluid therein). 5, hydrocele produced by the accumulation of fluid in the tunica vaginalis and lower portion of the funicular process; this is spoken of as a testicular hydrocele.

allowing the abdominal viscera to descend into the scrotum. This is called a *testicular* or *congenital hernia* and is usually manifested within the first year or two of life. The spermatic cord and vessels are imbedded in the wall of the sac but can be separated from it if necessary. If the funicular process becomes obliterated only in its distal part, the portion persisting at the proximal end gives rise to a *funicular hernia*, which is perhaps the most common type. The term *infantile hernia* is used to describe a hernia whose sac for some reason forms close to, but not into, the funicular process. It is likewise common but is differentiated with difficulty from the funicular type, even at operation. If the funicular process is obliterated at its proximal, but not at the distal, end, fluid may accumulate in the latter portion of it and in the tunica vaginalis, thereby forming a hydrocele (Fig. 2). Occasionally, the process will be obliterated at each end but will be open at some intervening portion; accumulation of fluid in such a sac is known as hydrocele of the cord. The *canal of Nuck* in the female corresponds to the processus vaginalis in the male and may be the source of herniation of the oblique (indirect) type of hernia. If the canal becomes obliterated everywhere except at one area near its midpoint, as it may do on rare occasions, a hydrocele of the canal of Nuck is formed.

Indirect hernias occur in young people, enter the abdominal (internal) ring, and descend by way of the inguinal canal (Fig. 3). There is a tendency for them to increase in size and progress in their descent, regardless of the type of congenital defect originally present. When the hernia descends past the subcutaneous (external) ring it is called *complete*. When it reaches the scrotum it is spoken of as *scrotal* (Fig. 4). In the female, the hernia may descend so far as to enter the labia majora, the homologues of the scrotum, and is called a pudendal hernia. The symptoms produced have already been amply described and consist chiefly of the appearance of a mass and a moderate amount of pain at the onset which gradually diminishes, but is supplanted by a feeling of heaviness and discomfort. The classical way to detect an inguinal hernia is to invaginate the skin of the scrotum up into the external ring of the canal with the index finger, and have the patient cough. If a hernia is present, a protrusion is felt with the finger tip when the patient coughs.

Hernias are occasionally associated with undescended testicle. Conversely, most undescended testicles are associated with a hernia. Hernia is also nearly always present with a hydrocele.

Direct Inguinal Hernia. These hernias are spoken of as acquired since there is no congenital preformed sac present. On the other hand, they depend upon the presence of a weakened transversalis fascia and oblique muscles. They almost always make their exit



Fig. 3. Left inguinal hernia in a boy six years of age. Frequently more of the mass would descend into the scrotum than is shown in the photograph; however, aside from the mere presence of the hernia, very few symptoms were experienced.

from the abdominal cavity at the "weak spot" in Hesselbach's triangle. This weak spot is located behind the lower fifth of the inguinal canal between the deep epigastric artery and the outer edge of the rectus muscle. As the herniation progresses anteriorly it practically always breaks into the inguinal canal, since this direction offers the least resistance. The sac presents through the external ring, is usually small and globular, and possesses a wide neck. It is, therefore, rarely the site of strangulation. Rarely does it descend into the scrotum (Fig. 5). Direct hernia occurs practically only in men and, as a rule, occurs later in life than does an indirect hernia; it is frequently bilateral. Aside from the protrusion and perhaps mild dull pain, it produces few symptoms.



Fig. 4. Scrotal hernia (indirect). This man aged
had a hernia for 12 years; it has never been ir-
ducible, but for the past six years it has descended
times into the scrotum.

Differential Diagnosis of Inguinal Hernia. In the consideration of differentiation between inguinal hernia and other lesions in the inguinal region, the history of the development of the mass will frequently point to the correct diagnosis. For example, the history of reducibility is practically always present in the early stages of hernias, although adhesions may form later and result in irreducibility. When a hernia mass is present, an impulse will be detected over it when the patient coughs; when no mass is present, coughing usually results in a protrusion which can be detected by the examining finger. This characteristic is almost pathognomonic of hernia. However, when a hernia becomes in-



Fig. 5. Bilateral direct hernia in a 55-year-old man. The hernia on the right is not visible, but a definite protrusion is palpable upon coughing. Direct hernias are usually no larger than that observed on the left side; they strangulate infrequently and practically never descend into the scrotum.

flamed or strangulated, it may be impossible to detect an impulse, although a mass can be felt and there will, of course, be a history of rather sudden onset of pain accompanying the inflammation or strangulation. Occasionally, it may be difficult to distinguish between an inguinal and a femoral hernia, but an inguinal hernia always presents above Poupart's ligament, whereas a femoral hernia presents below the ligament, although the mass may extend upward and overlie it. Hydrocele may simulate inguinal scrotal hernia, but careful examination will rarely fail to make the correct diagnosis. When the mass is a hydrocele there will rarely be a history of reducibility, but there may be a gradual increase in size. An important feature is the shape. The hydrocele is pear-shaped, whereas the scrotal hernia is more cylindrical or globular. The percussion note over a hernia will be tympanitic, and peristaltic gurgling can frequently be heard by auscultation. On the other hand, the percussion note over a hydrocele is flat and no auscultatory sounds will be heard. If the hydrocele is small, it will be possible to demonstrate that the external inguinal ring is empty. There is, of course, no impulse over the hydrocele upon coughing, unless there is an associated hernia, which, however, frequently occurs. Light is transilluminated through a hydrocele but rarely through a hernia. In a chylous hydrocele (containing cholesterol), light will not be transmitted.

Enlargement of the inguinal lymph nodes may occasionally be confused with a hernia of the irreducible type. A lipoma over or in the inguinal canal presents a similar difficulty. Again, it is important to review the history of the development of the mass since reducibility is so constantly present some time or other in the course of a hernia. Acute inguinal lymphadenitis will usually be associated with pain and other inflammatory signs which, however, may also be demonstrable over a strangulated hernia. The sudden development of symptoms accompanying strangulated hernia is usually sufficient to establish a correct diagnosis (see Chap. 33). Occasionally, a psoas abscess may present in the inguinal region and produce a bulging mass which resembles a hernia. In such a case, the spine should be examined for the presence of Pott's disease.

Differentiation between direct and indirect hernia is of great importance at operation insofar as more meticulous care is required in repair of a direct hernia. As previously mentioned, the most important anatomic feature in the differentiation is the relation of the neck of the sac to the deep epigastric artery (Fig. 6). An indirect hernia passes through the internal ring into the inguinal canal lateral to the deep epigastric artery, whereas a direct hernia passes into the lower portion of the inguinal canal medial to the deep epigastric artery. Unfortunately, this important feature can rarely be made out by external examination. At operation, however, this relationship of the sac to the artery is easily demonstrable. Moreover, in direct hernia the spermatic cord usually lies in front of and external to the sac, whereas in indirect hernia the cord usually lies behind and internal to the sac. As stated previously, direct hernia occurs more frequently in older people than does the indirect hernia; it rarely descends into the scrotum, whereas the indirect

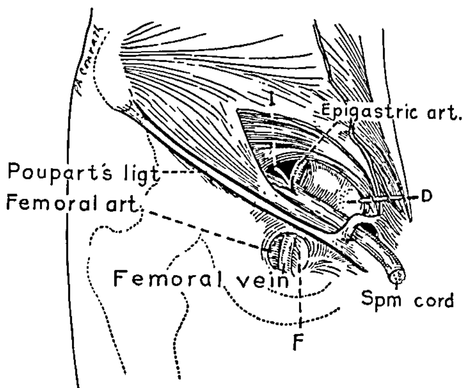


Fig. 6. Diagram to illustrate the sites of herniation of the three common hernias occurring in the inguinal region. I, indirect; D, direct; F, femoral.

hernia frequently does. The shape of the sac of the direct hernia is significant since it is usually globular (not elongated); the defect in the abdominal wall is large, considering the small size of the hernia.

TREATMENT OF INGUINAL HERNIA. Inguinal hernia can be cured only by operation which, in general, should be carried out as soon as the diagnosis is made unless there is a good contraindication. Inguinal hernia in infants can occasionally be cured by reducing the hernia and applying a yarn truss which, however, must be worn constantly for several months and must be tight enough to maintain reduction yet carefully kept in place. To most mothers this is difficult and imposes upon them too great a responsibility. Since the operation in infancy is so simple and safe, and requires hospitalization for but a day or two, the use of the yarn truss is becoming more and more of historical interest. Moreover, after the age of one year, hernias in infants are rarely curable by this conservative treatment. In elderly people, the question of operability presents itself. If the patient is no longer required to work, and the presence of a hernia produces only moderate symptoms, operation may not be indicated, particularly if the hernia is of the direct type. As a routine method of treatment, the use of a truss is to be condemned; in only a few instances will a properly fitted truss be a justified form of treatment.

One of the strongest reasons for advising operation is the tendency for a hernia to become irreducible if it is not already so, with the inevitable likelihood of strangulation and its threat to life. Operation is particularly indicated if manifestations of obstruction or strangulation were ever present while the hernia was irreducible. A hernia in which the neck of the sac is small is more apt to strangulate than is a hernia with a large sac; this factor also affects the decision to operate. This is particularly true of indirect inguinal hernia; direct inguinal hernia rarely strangulates.

The modern *operation* for the cure of inguinal hernia has many variations but its essential steps are: first, opening the inguinal canal; second, careful dissection of and high ligation of the sac; third, closure of the canal. These features were first described independently by Halsted and by Bassini over

50 years ago. The variations in the operation are mainly concerned with the third step, i.e., the method of closure of the canal after the sac has been eliminated. Ferguson did not transplant the cord; Bassini transplanted it *external to the approximation* of the internal oblique and conjoined tendon, with the shelving portion of Poupart's ligament; Halsted transplanted the cord external to the external oblique. It is important to notice however that Halsted later described an operation in which the cord was not transplanted. Indeed, of the three surgeons usually stated as originators of the modern operation (i.e., Halsted, Bassini, and Ferguson), Halsted is the only one who continued, after his original publication, to write about his experiences during which he made additional contributions to the subject. Thus it may be stated that he probably did more toward the gradual perfection of inguinal herniotomy than any other surgeon.

It is impossible to state just which type of hernia repair is the best, partly because many are equally good, but especialy because one may be superior with a certain hernia defect and not so good with another. The Ferguson operation, not transplanting the cord, is a simple procedure and entirely adequate for children. In infancy and young children under three or four years of age, an even simpler procedure consisting of ligation of the sac without a plastic repair is adequate. However, when hernias occur in adult life most surgeons now feel that the Ferguson operation will be followed by a high rate of recurrence in the indirect hernia as well as the direct type. Regardless of the type of repair, the rate of recurrence will be higher in direct than in indirect hernias. The authors concur in the opinion expressed by Lehman and Davis (5) that a Bassini type of repair (transplantation of the cord with suture of the transversalis fascia, conjoined tendon and internal oblique muscle to the inguinal ligament), should always be used in indirect hernias if there is the slightest weakness of the transversalis fascia. Transplantation of the cord should be done in practically all direct hernias.

Additional features include suture of the cremaster muscle to the internal oblique for additional support, which was recommended by Halsted in 1903. Halsted also suggested the use of a flap of the anterior rectus sheath in cases where the conjoined tendon was atrophied or weak. He also described a relaxing incision in the internal oblique aponeurosis as it joins the rectus, thus permitting the conjoined tendon to be sutured without tension to Poupart's ligament. During recent years, there has been an almost universal shift from the use of chromic catgut in the repair of hernias to the use of silk (as originally recommended by Halsted), or cotton. Unquestionably, the percentage of recurrence will be reduced by silk or cotton. The use of fascia as an additional detail in the repair of hernia is mentioned below.

In the repair of any hernia, it is extremely essential that the structures sutured in apposition consist largely of solid fascial tissue. Its importance is demonstrated by the experimental work of Seelig and Chouke (1923) who noted that suture of muscle to muscle, or even muscle to fascia, did not result in so strong a union as when both structures consisted of fascia. It is obvious then that when an inguinal hernia is repaired, the conjoined tendon instead of the internal oblique muscle should be sutured to Poupart's ligament if possible. Tension in suturing the structures in a repair should be avoided, since it is an important factor in the development of recurrence, particularly if catgut is used. To avoid tension at the suture line, a relaxing incision can be made in the rectus fascia above the conjoined tendon. Important in the repair of any inguinal hernia is the repair of the defect in the transversalis fascia, bringing it down to the inguinal ligament (Bassini).

In an effort to prevent recurrences which are apt to follow even expert repair, McArthur (1901) described the use of fascia from the external oblique aponeurosis as a suture to increase the solidity and permanency of the repair. The authors wish to emphasize the importance of using a strip of fascia about 0.5 cm. wide cut from the external oblique aponeurosis, as McArthur originally described. By leaving the central end attached at the pubic tubercle, a strip of ample length can be obtained to reinforce the suture line. This should be done on all hernias when the structures are weak, or when approximation by the sutures is ob-

tained only by tension. It has been shown that, if a strip of fascia is utilized after the McArthur technic, recurrences will be eliminated almost completely (6), especially if a relaxing incision is made in the internal oblique fascia near its attachment with the anterior rectus fascia. Strips of fascia lata removed from the lateral aspect of the thigh may also be used (Gallie and LeMesurier, 1921). The defect in large hernias may be so great that a satisfactory repair cannot be made without the use of these fascial strips which are used to reinforce the suture line, especially that approximating conjoined tendon and Poupart's ligament.

As stated previously, the development of strangulation makes immediate operation imperative. The decision as to the type of operation to be performed in such instances depends upon such factors as duration of strangulation, amount of intestine involved, and condition of the patient. Frequently, these factors will prevent the performance of a painstaking and orthodox repair; in fact, the patient's condition may be so precarious as to justify rapid closure without thought as to the possibility of recurrence.

Although herniotomy may be considered one of the simplest of the major operations, complications will appear in a surprisingly large percentage of cases. Very few complications will be encountered in patients under 20 years of age; after that age they increase in a direct ratio as the age increases. In a study of 2,000 herniotomies, Beekman and Sullivan (7) noted an incidence of 8.5 per cent of respiratory lesions; the incidence of atelectasis was 2.3 per cent, pneumonia 0.7 per cent, and pulmonary embolism 0.6 per cent. Although the incidence of pneumonia was greatest following general anesthesia, Beekman and Sullivan noted other respiratory lesions were decreased. For example, they found the incidence of all types of respiratory lesions to be 7.3 per cent following general anesthesia, 9.1 per cent following spinal, and 10.3 per cent following local anesthesia. The incidence of postoperative wound infection will vary from 1 to 5 per cent depending upon circumstances, but is observed by all surgeons to be much less following the use of silk or cotton. The mortality rate in inguinal herniotomy (exclusive of strangulated hernia), should be appreciably under 1 per cent. Complications of herniotomy, even in the aged, are reduced by the use of local anesthesia, silk or cotton sutures, and early ambulation.

In spite of the type of repair, recurrence will develop in 2 to 5 per cent of indirect and 4 to 8 per cent of direct hernias. In a series reported by Hagan and Rhoads (8), 50 per cent of the recurrences took place within two years following repair.

Sliding Hernia. Hernias of this type are caused by a slipping of the posterior parietal peritoneum on the underlying tissue, thereby allowing the colon to descend as a herniation (usually inguinal, rarely femoral). The identification of such hernias is rarely made, except at operation. Sliding hernias on the right side usually contain the cecum and appendix; on the left side, sigmoid. In either case, they are usually of the indirect type. If such hernias are small, no peritoneal sac may be present. As the mass enlarges, a fold of peritoneum descends with the colon, forming a sac on the anterior portion of the mass. Sliding hernias descend so readily that a truss is rarely satisfactory in maintaining reduction. Operative repair is usually difficult. If the hernia is small, the lack of a sac may lead the surgeon into the error of mistaking the colon for the sac and opening it. After mobilization of the colon, and separation of adhesions between it and the sac, it is frequently advisable to anchor the colon to the posterior wall of the pelvis. Repair of the defect may be difficult because of the large size of the opening through which the mass herniates and absence of adequate fascia to close the defect. The recurrence rate in sliding hernia is high, although Sensenig and Nichols (9) report only four recurrences in 53 cases observed two years after operation. (Presumably only about 50 per cent of recurrences will develop by that time.)

Femoral Hernia. This type of hernia occurs much more commonly in women than in men (ratio about 3:1) and is confined almost entirely to adults, although it is slightly less common even in women than the inguinal variety (Fig. 7). The hernia makes its descent into the femoral canal through the femoral ring, located in the floor of the peritoneal cavity. Weakness of Gimbernat's ligament, which bounds the femoral ring on the

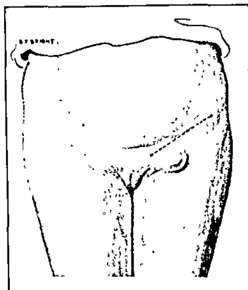


Fig. 7. Femoral hernia in a woman. Note that the mass which decends through the femoral canal is located below Pourpart's ligament, which is indicated by the dotted line.

inner side, is apparently the most important factor in the development of a femoral hernia. The fact that this ligament is more poorly developed in women than in men presumably accounts for the greater incidence of femoral hernia in women than in men. The *femoral canal* represents the narrow space between the femoral vein and the inner wall of the femoral sheath. Normally it is only about half an inch long and contains nothing more than a few lymphatic vessels and a little fat. As the hernia descends into the femoral canal it soon reaches the saphenous opening which offers little resistance, thereby allowing the hernia to appear in the soft tissues of the thigh. In general, these hernias are smaller than inguinal hernias and, indeed, may be present without a mass or other external manifestations.

The *clinical manifestations* of uncomplicated femoral hernia are not unlike those described for hernias in general. However, because of their small size, they are apt to contain only omentum and therefore present so few symptoms and signs that they are frequently unnoticed by the patient. Such hernias may even strangulate and be unnoticed externally. However, if a loop of bowel is strangulated, the manifestations of intestinal obstruction will be so obvious that laparotomy is demanded.

If the omentum becomes adherent to the sac, there may be a dragging type of dull pain. The pain may be due entirely to pressure in the nearby femoral nerve. When intestines descend into the sac, the pain is apt to be more severe and be colicky because of obstruction. The hernial mass appears below Poupart's ligament at the saphenous opening and rarely attains a size larger than that of a hen's egg. At times, the mass may extend upward over Poupart's ligament and thereby simulate inguinal hernia, inguinal lymphadenopathy, and the like. The similarity of a saphenous varix to a small femoral hernia should be emphasized because of the obvious difference in treatment. Although a saphenous varix is soft and compressible, as is a hernia, the varix disappears spontaneously when the patient lies down. When the patient coughs, an impulse but no protrusion will be palpated over the varix. The skin over the varix may be bluish; frequently there are varicose veins on the extremity.

Strangulation is frequently encountered because of the narrow sac and the sharpness of the edge of Gimbernat's ligament. For the same reason, the femoral ring is perhaps the most frequent site for *Richter's hernia,* which is apt to produce a strangulation of the small portion of the intestinal wall which is pinched in the neck of the sac. Cramping pain, perhaps of a disabling type, is present, even though the entire lumen is not blocked; other manifestations of strangulation are not apt to be present because the mesenteric vessels are not involved. Diagnosis may be extremely difficult because of the small size or absence of a hernial mass and the lack of complete obstruction. Tenderness is a very important diagnostic sign but may be the only significant local finding. Immediate operation, of course, is imperative because of the tendency for the rapid development of gangrene and perforation. In fact, any type of strangulation in femoral hernias is usually associated with the early development of gangrene on account of the narrowness of the ring.

The *treatment* of femoral hernia is surgical. A truss will rarely fit the patient and maintain reduction of the mass. Moreover, the mass frequently protrudes beyond the

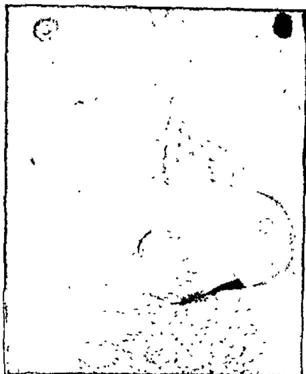


Fig. 8. Postoperative (incisional, ventral) hernia. The hernia developed two years after an operation for repair of a perforated ulcer. It is reducible and associated with only slight pain.

truss; strangulation is thereby encouraged. Even in the absence of symptoms, repair is wise to prevent likely and serious complications, such as strangulation and early gangrene.

Although repair by way of the inguinal route will be followed by fewer recurrences, this procedure adds somewhat to the intricacy of the repair and should not be attempted by the unskilled surgeon. The results through the femoral route alone should be satisfactory except in the large hernias. When the right lower quadrant is explored for intestinal obstruction or other abdominal symptoms of unknown origin and a femoral hernia found, the repair of the sac after reduction of the mass is done by a simple pursestring suture.

Postoperative (Incisional, Ventral) Hernia. This type of hernia is unfortunately common (Fig. 8), but can be prevented to a great extent by careful aseptic technic and proper closure of abdominal wounds. Suppuration of the wound is conducive to the formation of hernias but cannot always be avoided when intraabdominal abscesses are drained. Thus, hernia is apt to follow operations for drainage of intraabdominal abscesses (e.g., appendiceal abscess). Poor technic in closure; including insecure knots and tight sutures placed close to the edge of the fascia are common errors. Postoperative hernias are also prone to occur in fat people. Any pulmonary complication which results in frequent coughing during the first five or six postoperative days may lead to partial deep suppuration of the wound to pave the way for the development of a hernia, or even to produce a complete separation of the wound which usually demands immediate closure. Certain types of incisions are less apt to be followed by herniation than others. Transverse incisions are less likely to be followed by hernias than other types. The so-called "paramedian incision," made through the rectus fascia, retracting muscle outward, is less apt to be followed by a hernia than an incision in the midline, because the rectus muscle falls over the line of suture and supports it when the wound is closed. Obviously, incisional hernias are nearly always abdominal, but on rare occasions may be located elsewhere (e.g., transpleural hernia of the thorax).

If the fatty subcutaneous tissue is thick, the hernial mass may burrow for a considerable distance subcutaneously, especially downward, because of gravity. Occasionally, it may enlarge in a mushroom fashion until a large proportion of the contents of the abdominal cavity are contained in the sac. The omentum, and frequently loops of intestine, become adherent to the sac so that the greater portion of the hernia may become irreducible. When the hernia first develops, the patient nearly always complains of a dragging pain arising in the neighborhood of the scar, perhaps radiating deep into the abdomen. Early in the formation of the hernia, tenderness at the site of the defect is pronounced. When the hernia develops within a few days following laparotomy, because of partial rupture of the deep layers of the wound, the intestines herniating into the defect may, at times, become adherent and lead to postoperative obstruction. Usually, however, definite evidence of a hernia is not demonstrable, subjectively or objectively, for several weeks or months following operation. Besides the dragging pain mentioned above, other symptoms, including constipation, anorexia, cramping

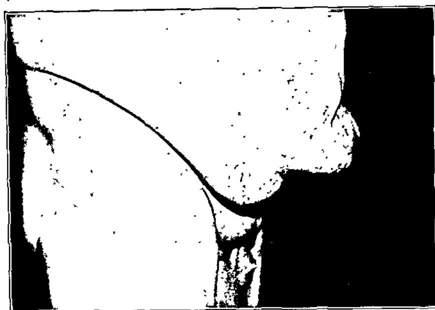


Fig. 9. Lateral view of an umbilical hernia in a man, aged 50. The mass had been present for 15 years, had never been strangulated, but for many years had been incompletely reducible.

pain, and even vomiting, may develop. Strangulation is not usual because of the large ring.

The *treatment* depends to a great extent upon the size of the hernia and the condition of the patient, especially his age. If the hernia is reducible and has a large opening, the patient may be fitted with a large elastic belt or support which, in general, may relieve the symptoms if applied correctly, i.e., when the patient is lying down and the hernia is reduced. If the belt does not relieve the symptoms, or the patient is young and still active physically, *operative repair will be indicated.* At operation, the contents of the hernia are reduced, and the sac, which is frequently multiloculated, *excised*; the peritoneum and fascia are then closed. When a large part of the abdominal viscera (ileum, colon, omentum, spleen, and so forth) have become herniated, the resultant decrease in the size of the peritoneal cavity may make reduction difficult. The fascia must be dissected free from fatty tissue, overlapped, and anchored with interrupted sutures of silk. If the defect is too large to allow satisfactory closure without undue tension, it may be necessary to resort to the use of patches of whole skin or more commonly to strips of fascia lata as reinforcing sutures.

In addition to autogenous fascia lata, numerous other substances have been recommended recently to aid in the repair of large hernias. Artificial prostheses, such as tantalum wire, and stainless steel wire mesh, have also been used to fill in the defect. In a comparative study of tantalum wire and stainless steel wire mesh Spencer and associates (10) report that neither proved superior to the other; they fragmented with equal frequency. When a whole-thickness skin graft is used, *there is danger of formation of cysts,* but these are usually prevented if the graft is inserted under tension. The greatest *disadvantage of the use of these substances is postoperative infection.* Actually they are rarely needed.

Umbilical Hernia. With few exceptions, hernias of this type are caused by a congenital defect of the abdominal wall at the umbilicus and appear either in infancy or in late adult life (Fig. 9). Normally, the umbilical ring closes after the cord is ligated, and its contents atrophy, resulting in scar tissue which forms a firm support at the umbilicus, covered by skin. Hernias at the umbilicus develop most commonly during *infancy* (up to two years) and are supposedly caused by an unusual strain causing rupture at a weak point, allowing a protrusion of a peritoneal sac, which is small and usually contains only omentum. The first evidence of *hernia rarely*

produces any demonstrable symptoms. Unless treated it may enlarge until intestine also protrudes into the sac. In children, the neck of the sac is small (1 to 1.5 cm. in diameter) but may attain a size two or three times as large. Up to two or three years of age spontaneous closure may follow if a strip of adhesive is placed transversely across the abdomen over the umbilicus tightly so that the skin folds inward. Almost constant fixation must be maintained for several months before closure of the defect may be expected. Even if this occurs, recurrence is possible years later. After the age of 18 months, this type of conservative therapy will be increasingly unsuccessful, regardless of whether or not it has been in use previous to this time. Cure can then be effected only by operation.

Umbilical hernias in adults occur usually in the latter part of life and are three or four times more common in women than in men. Relaxation of the abdominal muscles during pregnancy, obesity, and debilitating diseases appear to be important etiologic factors. The herniation may take place directly through the umbilicus or a short distance to either side. Occasionally there are several openings. The omentum first protrudes into the hernia, but as the sac enlarges, intestine (usually colon) also is included. Adhesion of the sac to the omentum and intestine takes place early and is usually so extensive that the hernial mass is lobulated or divided into compartments. The skin over the hernia is thin and very little subcutaneous tissue intervenes between it and the contents of the sac. For this reason, peristaltic movements are readily demonstrable if intestines are included in the sac. The symptoms of umbilical hernia in adults may not be pronounced, but include such complaints as constipation, dragging pain, and anorexia, especially if the hernia is large. Cramping pain, nausea, and especially vomiting indicate partial or complete obstruction. On account of the thin skin and protrusion of the mass, the skin becomes traumatized readily and ulceration may develop. The longer the hernia persists, the more pronounced is irreducibility and the more common is strangulation.

The *treatment* of umbilical hernia in adults is operative repair. Elastic belts or supports usually fail to relieve symptoms and are usually harmful if the hernia is irreducible, which is usually the case, at least by the time the patient comes to the physician for relief. Operation consists of an elliptical incision made in a transverse direction (Mayo), excising a portion of the redundant skin and subcutaneous fatty tissue. Occasionally, it may be advantageous to make the incision in a longitudinal direction. If the hernia is large, it may be advisable to use fascial sutures in its repair.

Congenital Umbilical Hernia of the Cord (Omphalocele, Amniotic Hernia). In this hernia there is a defect in the entire abdominal wall at the umbilicus. The only coverings are parietal peritoneum and amnion; the wall over the hernia is therefore transparent, allowing visualization of the contents of the hernia (Fig. 10). The child is born with a globular shaped herniation varying from one inch to several inches in diameter, which may contain any or practically all organs of the abdominal cavity, frequently including most of the liver. The most likely cause or explanation is persistence of the omphalomesenteric ducts. Unless corrected by operation the condition results in a fatal peritonitis. Immediate operation is essential. When the defect is large, it will be impossible to close fascia to fascia at the first operation. If so, the amnion and peritoneum should not be opened (Johns, 11). The skin should be undermined and approximated; several weeks or months later the resultant hernia is repaired. Postoperative chemotherapy is important.

Diaphragmatic Hernia. Diaphragmatic hernia is a protrusion of abdominal viscera into the thoracic cavity through an opening of the diaphragm. In a study of 605 cases, Harrington (12) noted that 80 per cent occurred through the esophageal hiatus; 14 per cent were traumatic (all except one in this group were on the left side); 5 per cent were hiatus hernias due to a congenitally short esophagus; 13 per cent associated with a short esophagus caused by esophagitis or malignancy; 3 per cent were through a congenital defect in the posterior quarter of the left diaphragm; 2 per cent protruded through the parasternal foramen of Morgagni and an equal number through the pleuroperitoneal hiatus (Fig. 11). Hernias are designated as being through the pleuroperitoneal hiatus when there is lack of complete fusion between



Fig. 10. Omphalocele. At the left, photo taken immediately after birth. In the middle, photo taken a few hours later, following operation in which the amniotic membrane and peritoneum were removed and the abdominal skin closed. At the right, photo taken at two weeks of age, one week after the second operation during which the contents of the sac (liver, transverse colon, and rest of the small intestine) were reduced, the fascia of the abdominal wall mobilized and closed, and the skin sutured. To have done both procedures at the first operation might have jeopardized recovery because of respiratory embarrassment due to the sudden increase of intra-abdominal pressure following replacement of the abdominal viscera. This increase can be better tolerated after the baby has become adjusted to the normal breathing of extra-uterine life.

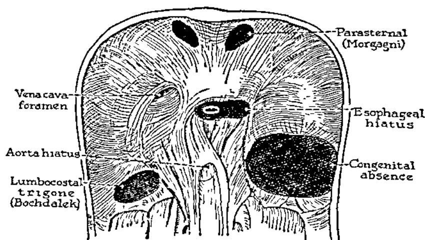


Fig. 11. The diaphragm viewed from below revealing numerous types of diaphragmatic hernias. Most of the traumatic hernias (not shown) will be on the left. (After Dorsey. Operative Technic, Appleton-Century-Crofts.)



Fig. 12. Diaphragmatic hernia in a child of five years; roentgenogram after barium enema. Note that the colon, as well as the stomach, has herniated through the defect in the diaphragm. A, anteroposterior view. B, lateral view.

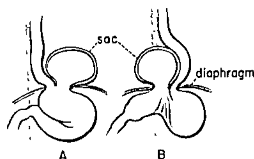
the septum transversum and the pleuroperitoneal membrane; when there is incomplete muscular formation of the diaphragm in this region of fusion the opening is called the "foramen of Bochdalek." Hernias through the former defect do not have a sac, whereas hernias through the latter do have a sac. Hernias through the two openings named above, those through the foramen of Morgagni as well as those associated with an absence of part of the diaphragm, are often spoken of as congenital (Fig. 12), and those through the esophageal hiatus as acquired; the former are usually present at birth, whereas the latter may not appear until late adult life.

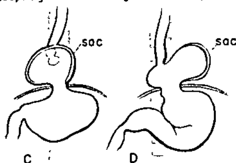
Harrington (12) classifies hernias through the hiatus into four groups (Fig. 13). In the paraesophageal hiatus hernia (13 per cent of his series), the esophagus is of normal length and is not elevated above the diaphragm (A and B). The stomach herniates alongside the esophagus, perhaps with other organs. Such hernias are usually not large. In a second type of hernia, designated as esophageal (67 per cent), the esophagus is of normal length but does not extend down to the hiatus (C and D). Such hernias are apt to be large; herniated viscera may ascend into either or both sides of the thoracic cavity. Esophagitis is common in this type of hernia. Failures following repair are common in this group. Hernias with a short esophagus (E and F) constituted 18 per cent of Harrington's group; 5 per cent had a congenitally short esophagus, and 13 per cent had shortness secondary to esophagitis or tumor.

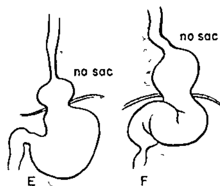
Traumatic hernias may be caused by tears, stab wounds, and the like. Very few of these will be associated with a sac.

The *clinical manifestations* of diaphragmatic hernia are varied and, in many instances, are absent, the diagnosis being made radiologically. When the herniation is secondary to a *congenital* absence of a large portion of the diaphragm, symptoms are usually severe and are manifested soon after birth. These manifestations consist of dyspnea, cyanosis, tachycardia, constipation, and occasionally symptoms of intestinal obstruction. Vomiting may be persistent. Hiccup is not uncommon. X-ray examination may reveal a displacement of the heart, thereby explaining the cardiac symptoms. Frequently, congenital hernias exist for years without producing any symptoms whatsoever.

The manifestations of the *acquired* type







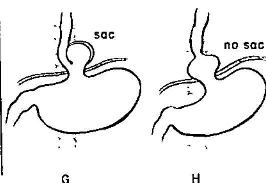


Fig. 13. Types of herniation through the esophageal hiatus. (Modified from Harrington.)

(hiatus hernia) are rarely so acute as those mentioned above. Pain radiating upward into the shoulder or downward into the peritoneal cavity may be the first complaint. Digestive symptoms, such as anorexia, nausea and vomiting, or regurgitation without premonition, are not uncommon. Symptoms are so inconstant that they may simulate those of peptic ulcer, cholecystitis, or coronary disease. Dysphagia, hemorrhage due to ulceration, and even cardiac symptoms due to pressure of the herniated mass may occur. Auscultation of the chest may reveal gurgling sounds over the left chest, but this may not be of great diagnostic aid, because of the transmission of such sounds upward from the stomach in normal individuals. A tympanitic note to percussion over the left chest should lead one to suspect diaphragmatic hernia. A roentgen examination, especially with the barium meal or enema, will usually lead to the correct diagnosis (Fig. 14). When the hernia is small, it may recede upon standing, and symptoms therefore become decreased. In such instances, the x-ray examination must be performed with the patient in the prone position, since gravity will pull the stomach downward while the patient is standing and thereby reduce the hernia. It should be emphasized that the demonstration of a hiatus hernia by x-ray is no indication that the patient's symptoms are due to the hernia.

The hernia destroys the sphincteric action of the diaphragmatic crux and the resulting reflux of gastric secretion produces an esophagitis in the majority of patients. Many of the symptoms including pain, pyrosis, and bleeding are caused by the esophagitis.

On some occasions, it may be difficult to differentiate true diaphragmatic hernia from an *eventration of the diaphragm.* In the latter instance the diaphragm is elevated to an unusual height and is rarely mobile, thereby indicating that a disturbance in the innervation exists.

As stated, *traumatic* hernias are caused by

Fig. 14. Two examples of esophageal hiatus hernia (x-ray after barium). The position of the diaphragm is indicated by the broken line ---D. A constriction of variable degree is produced at the hiatus.



Fig. 15. Traumatic diaphragmatic hernia. The patient, a male aged 34, had an auto accident five nonths previously. Injuries consisting of intracranial damage (unconsciousness for four weeks), and fracure of the humerus and ribs were so serious that nothing was done at that time for the hernia which roduced only mild dyspnea and pain upon breathing. When repaired, stomach and a large part of the mall intestine and colon were found in the thorax. Left, x-ray before barium. Note the marked shift of ne mediastinum to the right. Right, x-ray after barium.

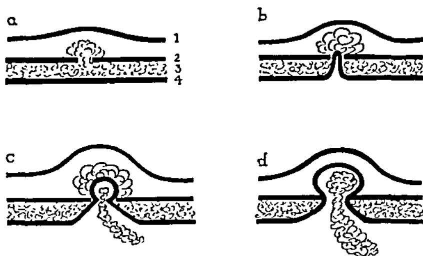


Fig. 16. Epigastric hernia and subserous lipoma. a, subserous lipoma, after breaking through sheath of rectus. b, subserous lipoma with some peritoneum pulled up into the fascial slit. c, subserous lipoma with a hernia sac containing some protruded omentum (epigastric fatty hernia). d, simple epigastric hernia, without lipoma. (Redrawn from De Quervain. Clinical Surgical Diagnosis, Wm. Wood.)

injury of the direct or indirect type (Fig. 15) and may or may not be associated with symptoms at the time of injury. Obviously, a sac is rarely present. Symptoms are dependent to a great extent upon the time and extent of herniation. The manifestations are similar to those described under the acquired type.

The *treatment* of diaphragmatic hernias is surgical, but on many occasions, small hernias produce such few symptoms that repair is not necessary. Either the thoracic or abdominal route may be used in the repair. Repair usually results in healing of the esophagitis because the sphincteric action is restored.

Interruption of the phrenic nerve may at times be a very helpful procedure in treatment, particularly in adults. Temporary interruption by crushing the nerve with a clamp will immobilize the diaphragm in an elevated position which will thus allow healing without a strain on the suture line. In the average esophageal hiatus hernia, permanent paralysis (by cutting the nerve) will rarely be indicated, except perhaps when the esophagus is congenitally short. Occasionally, in elderly debilitated patients, one may be justified in doing nothing more than crushing the nerve since this procedure is apt to alleviate or eliminate symptoms of small hernias. Cutting the phrenic nerve in elderly patients with a large hiatus hernia and with inadequate physical reserve to tolerate repair of the hernia, will yield very good results in over half the cases.

Internal Hernia. There are a number of fossae or depressions located chiefly on the posterior peritoneal surface of the abdominal cavity, as well as abnormal openings in the mesentery, into or through which small loops of intestine may rarely herniate. The most important of these are the duodenal (inferior, superior, and paraduodenal) and cecal (ileocolic, ileocecal, and retrocecal). Such hernias are diagnosed only at operation, which is usually performed because of symptoms of intestinal obstruction.

Miscellaneous Types of Hernia of the Abdominal Wall. There are many different kinds of hernia in this group, but all except the epigastric type are extremely rare. An *epigastric hernia* frequently consists of nothing more than a protrusion of properitoneal fat (properitoneal hernia) through a tiny opening in the linea albea (Fig. 16). Occasionally, a definite sac containing omentum forms and protrudes past the external fascia layer. They may or may not be reducible; on most occasions, a small tab of omentum remains attached at the neck of the sac. If the hernia is reducible, a protrusion may be detected upon coughing. Most epigastric hernias are asymptomatic. However, on rare occasions, they *produce pain in the epigastrium* which may be confused with various intraabdominal

lesions. In such instances, repair will be indicated. *Lumbar hernia* is one which appears in the lumbar region, usually through Petit's triangle or the space of Grynfelt. An *obturator hernia* passes through the obturator foramen of the innominate bone but usually presents no external manifestations. *Perineal hernias*, also extremely rare, occur usually in women and make their exit in the perineum at a variety of "weak points." *Sciatic hernia*, which is so rare as to be a surgical curiosity, passes out through either the greater or less sacrosciatic foramen. A *Spigelian hernia* is one presenting through the Spigelian (semilunaris) line; it is very rare.

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35

THE MAMMARY GLAND

The Normal Mammary Gland
Chronic Cystic Mastitis
Cysts
Benign Neoplasms
Malignant Neoplasms
Infections
Miscellaneous Lesions

The mammary gland is a superficial and readily observable organ, yet early diagnosis of its lesions may be difficult, particularly neoplastic disease, to which it is especially prone. Simple clinical examination, such as inspection and palpation, while of primary importance, is often neglected. Accurate findings presuppose definite knowledge of normal structures.

THE NORMAL MAMMARY GLAND

The breast, one of the secondary sex organs in the female, begins to develop with the onset of puberty, when it rapidly undergoes enlargement due primarily to the growth of the parenchyma, consisting of acinous (secreting or lactiferous) cells and the collecting ducts. The supporting framework consists mainly of hyaline connective tissue around the ducts and the numerous fibrous strands which support this growing mass of tissue, extending outward toward the nipple and the skin and called the suspensory ligaments of Cooper.

No other organ varies so widely in size and configuration as the female mammary gland. These variations depend upon differences in the amount and thickness of the subcutaneous fat, of the degree of development and tenseness of the supporting ligaments, and finally of the size and extent of the parenchyma. The latter consists essentially of about 20 ducts, each emptying into the nipple and branching proximally into many smaller ducts and acini somewhat like clusters of grapes. On gross palpation the breast may be firm and elastic, or soft and compressible, depending largely upon the relative amount of subcutaneous fat, hyaline connective tissue and parenchyma. Thus, in the patient whose breast contains a thin layer of subcutaneous fat and little connective tissue, the parenchyma normally yields a nodular sensation on palpation, which is distinctly firmer than the subcutaneous fatty tissue. On the other hand, the firm, elevated breast, well supplied with supporting connective tissue, may encompass the parenchyma to such an extent that little or no nodularity is felt. The grossly nodular or shotty character exhibited by many mammary glands is usually described erroneously as chronic cystic mastitis, a condition which will be discussed later. Variations in size are normal unless true hypertrophy occurs to a degree embarrassing to the patient. The breast is often pendulous in both young and older women, particularly after repeated lactation.

In the center of the pigmented areola is the nipple, or teat, a rounded conical projection at the apex of which the ducts that drain the parenchymal tissue empty. The nipple is supplied with muscle fibers and is a truly erectile organ, responding often to mechanical stimulation but frequently remaining retracted, particularly in young girls. This retraction is of little significance, except that it may interfere with nursing during lactation. Retraction of the nipple as a sign of cancer is discussed below.

The female mammary gland develops at puberty in response to awakening endocrine activity and is also influenced during normal adult life by the cyclic variations in the pro-

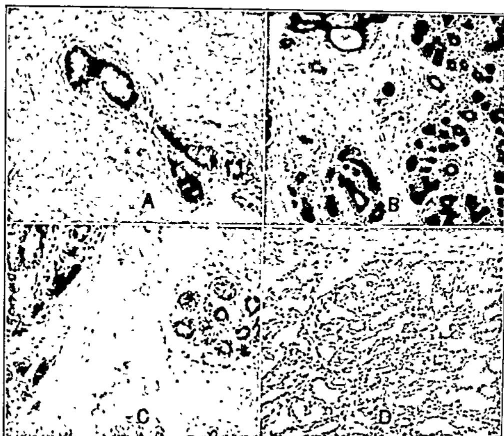


Fig. 1. The normal female breast; photomicrographs of the parenchyma under various physiologic conditions. A, before the onset of puberty. B, the hyperplastic breast during menstruation. C, the resting breast, showing the usual involution associated with the cessation of menstruation. D, the lactating breast; note the absence of stroma and the many acini filled with milk.

duction of ovarian hormones occurring each lunar month with the appearance of menstruation. More pronounced changes, of course, occur during lactation. The same sex hormones (estrin and progestin) which produce changes in the uterus also provoke changes in the breast. The patient is often made aware of these variations by a sense of fullness and pain in the breast before or during each menstrual period. Indeed, these changes have been confirmed by microscopic studies of the breast parenchyma, made at intervals. These histologic changes are shown in Figure 1. With the onset of lactation, the enlargement may be so rapid as to provoke considerable pain. Involution occurs with the subsidence of lactation. At the menopause, in most women, the parenchyma undergoes gradual involution or atrophy.

A careful routine is important in the examination of the female breast which should be done with the patient in both the sitting and the recumbent positions. Inspection with the arms extended overhead and with the patient bending forward is also advisable. Good illumination and exposure are essential. The parenchyma is first felt against the anterior chest wall and pectoral muscle with the tips of the fingers and the palm of the hand. Often a mass, or nodule, which might otherwise escape detection may be felt if the examiner stands behind the patient and palpates the breast with the palm of the hand. The skin over the breast is also examined, especially for retraction or attachment to the underlying parenchyma. No examination is complete without careful search for enlargement of the axillary lymph nodes. Palpation is most accurate if the finger tips are first placed on the outer side of the axilla before pressing against the chest wall and palpating downward and forward in the direction of the ribs (Fig. 2). By this maneuver the nodes are not pushed into the apex of the axilla before they can be palpated by the fingers. The axillary lymph nodes may be normally pal-

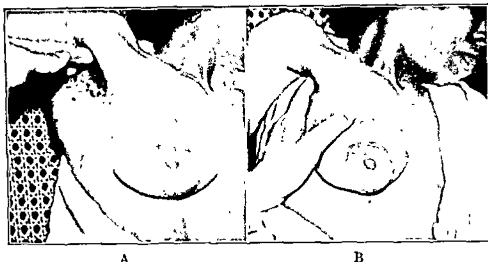


Fig. 2. Palpation of the axillary lymph nodes. A, the tips of the examiner's fingers are placed high in the axilla with the patient's arm abducted; the back of the hand lies along the upper end and head of the humerus. B, as the patient's arm is brought to the side the examiner's fingers are brought against the chest wall, palpating any nodes by rolling them between the pad of the finger tips and the ribs of the thoracic cage.

pable as small, shotlike structures. It is important for the novice not to mistake the rounded contour of the ribs for enlarged nodes. The lymph nodes above the clavicle are also noted because they become enlarged and palpable occasionally, especially in malignant disease.

Neoplasms are the most important of the many diseases which occur in the breast. Second are the inflammatory lesions or infections. Finally a miscellaneous group will be considered. These conditions apply almost entirely to the female breast.

The male breast, a tiny rudimentary structure composed of a few ducts and mostly connective tissue, is only rarely the seat of disease; inflammatory and neoplastic lesions occur, the latter not infrequently malignant. In any case, they present similar features and in most instances require the same treatment as in females. Details of breast lesions may be found in books on the breast (1, 2).

CHRONIC CYSTIC MASTITIS

In reality a term related to microscopy, this designation is usually, though erroneously, applied clinically to the exceedingly common "nodular breast." Other terms for this lesion include: cystic disease of the breast, Schimmelbusch's disease, chronic interstitial mastitis, chronic lobular mastitis, cobblestone breast, nodular breast, mastoplasia, *mastopathia*, *cyclomastopathy*, and adenosis.

Pathology. Despite differences of opinion among pathologists as to the classification of the microscopic changes, the following basic changes are most common, so common, in fact, that few adult breasts will fail to show one or more of them (Figs. 3, 4). 1. *Adenofibrosis* is a term which we prefer to apply to those types of chronic cystic mastitis in which the fibrous tissue predominates and the glandular elements are scarce and often atrophic. 2. In *benign parenchymatous hyperplasia*, there is a moderate proliferation of glands and ducts without much change in structure; there is often a stasis of secretory products. 3. In *precancerous hyperplasia*, the hyperplasia is advanced with cells of atypical shape, plication, layering of cells, and increased mitosis (Fig. 5). 4. In *cystic disease*, the cysts are large but hyperplasia is minimal. Years ago Bloodgood applied the term *blue dome cyst* to the larger solitary cysts, because of their bluish color when exposed. When they are present, hyperplasia is rarely significant, and cancer is seldom encountered.

These changes in the breast are generally considered to be due to the reaction of the breast to the cyclic activity of the female sex hormones. It would seem also that an essen-



Fig. 3. Chronic cystic mastitis. Photomicrograph (low power) of tissue in a lump removed from a 42-year-old housewife who first noted the tumor one year previously; there was no pain or increase in size. Examination revealed a lemon-sized nodular mass, freely movable but attached to and part of the parenchyma. Note the numerous cysts, some distended with fluid, others lined by hyperplastic epithelium; higher power magnifications are shown in Figure 4. Nowhere was malignant tissue seen although four blocks were cut from various portions of the lump. The periductile fibrosis and round cell infiltration were not marked.



Fig. 4. Chronic cystic mastitis showing the walls of two cysts. Photomicrograph (high power) from the same specimen, represented in Figure 3. A, note the papillary ingrowth into the lumen of the cyst, i.e., a beginning intracystic papilloma. B, note the hyperplasia of the small ducts adjacent to the wall of a dilated cyst; the cyst is filled with fluid and lined by flattened epithelium.



Fig. 5. Chronic cystic mastitis with precancerous hyperplasia. There is considerable cell alteration with papillary overgrowth, but no invasion. This nodule was present seven months when removed. The patient returned one year later with a cancer on the diseased side. When hyperplasia of this degree is found, simple mastectomy may be indicated to prevent cancer. It should be stated that this indication is controversial.

tial feature of many of these changes is their failure to follow exactly the ebb and flow of estrogenic excretion. Most important is the failure of normal involution, so that by repeated stimulation at each menstrual cycle, during pregnancy, and perhaps also by sexual excitement, the hyperplastic changes outstrip the hypoplastic or involutional process. The only, yet decisive, question to answer regarding these changes is this: What is the relation, if any, of the hyperplasia in chronic cystic mastitis to the development of malignant disease?

Relation of Chronic Cystic Mastitis to Cancer. Since cancer is, after all, an abnormal growth of pre-existing cells, it is but natural that the proliferating epithelium in chronic cystic mastitis would be suspected of being an early cancer. Indeed, the dividing line between benign hyperplasia and malignant neoplasia in general is not always a sharp one. There is much controversy as to whether or not chronic cystic mastitis is a precursor of cancer. Years ago Warren (3) made an extensive study of this relationship in the Massachusetts female population. He concluded that "the breast cancer attack rate for women with chronic cystic mastitis and related lesions in the age group from 30 to 49 years is 11.7 times the rate for the Massachusetts female population; in the group over 50 years of age 2.5 times as great; in the entire group 4.5 times as great"; and that "chronic cystic mastitis and chronic mastitis (noninfectious) predispose to the development of breast cancer." Geschickter (4) and Copeland (5) have arrived at the same general conclusions, but it should be added that there are many pathologists and surgeons who do not agree that such a relationship exists. It is our own opinion that there is a danger of development of cancer in chronic cystic mastitis, but this danger is most significant in the type identified as "precancerous hyperplasia," and practically absent in the types identified as "adenofibrosis" and "cystic disease," previously described.

Clinical Manifestations. It must first be emphasized that chronic cystic mastitis is a bilateral disease, particularly from the standpoint of pathology. Often, clinical examination reveals bilateral firmness and diffuse nodularity, but on many occasions there is one "predominating" lump. It is this predominant lump which receives the attention because it may be cancer.

The *pain* is usually slight and brings the patient to the doctor only because it has aroused a fear that such a symptom may be a sign of cancer, even though no lump may

have been felt. Actually, of course, pain is not a manifestation of cancer except in the terminal stages when ulceration and infection have occurred. Indeed, severe pain is generally indicative of the presence of other lesions, such as acute mastitis and abscess. The pain in chronic cystic mastitis is rarely constant, being worse at some period during the menstrual cycle, usually just before or during the flow. In a few patients, however, the pain may be severe enough to be disabling and demand relief; under such conditions it is called mastodynia (p. 882).

Discharge from the nipple in chronic cystic mastitis is relatively uncommon, being encountered in less than 10 per cent of cases. In a study made by Hinchey (6), the discharge was bloody in about half the cases, and serous or greenish-brown in the remainder. The latter have no clinical significance. Discharge is more frequent in duct papillomas, and it is usually bloody; for example, Geschickter (4) noted a bloody discharge in 47 per cent of 204 cases studied. When duct papillomas are in or just beneath the nipple, they may be palpable, but when located in the depth of the breast, they are rarely palpable because of their small size. A significantly large proportion of these lesions is believed to undergo malignant change.

Examination reveals diffuse induration and nodularity. Tenderness is often noted throughout the breast but is usually most prominent over one or more of the nodules. As stated previously, there is usually a predominant nodule that is more important than the chronic cystic mastitis itself, because it might be a cancer. From day to day there is apt to be variation in the location of the tenderness, and actually in the size of the nodules; in general, the signs are most prominent just before and during the menstrual flow if the patient is still menstruating. There may be slight increase in size of the affected breast, but the lesion tends to develop in small breasts relatively free from fat. The nodules are poorly defined and are firm, but not stony hard. Since the surface is not smooth, they cannot be distinguished from malignant nodules.

Treatment. Treatment may be conservative or operative depending upon whether or not the presence of carcinoma can be eliminated. On certain occasions it will not be difficult to exclude malignancy. For example, if the patient is in her early twenties, and has bilateral tenderness and nodularity primarily during the menstrual period, conservative measures are indicated, particularly if the predominant masses change in size from time to time. At times, support with a properly fitted brassiere will relieve the pain although it will not influence the pathologic process. Female and male hormones have been used but are often ineffectual. It is well known that pregnancy and lactation have a beneficial effect on chronic cystic mastitis; if symptoms are severe, pregnancy should be encouraged.

If carcinoma cannot be excluded, *surgical excision* of the predominant nodule will be indicated. The excision should be carried out with a wide margin of adjacent breast tissue so that, if carcinoma is present, it will not be cut across during the excision. Moreover, excising adjacent tissue will include enough breast tissue to confirm the diagnosis of chronic cystic mastitis, since numerous small cysts will usually be found. A frozen section should be performed; if carcinoma is present, radical resection, including excision of the axillary contents and both pectoral muscles, should be carried out. Occasionally the pathologist will be uncertain from the frozen section as to whether or not the lesion is malignant. Under these circumstances, the surgeon must wait for the paraffin section. If the frozen or paraffin section reveals a severe degree of hyperplasia with much layering of cells, pyknotic nuclei, and mitosis, simple mastectomy is usually advisable (3, 7), on the theory that carcinoma is present somewhere in the breast or will develop. It should be added, however, that this point is controversial.

CYSTS

Cyst formation, as already mentioned, is one of the pathologic features of chronic cystic mastitis. These cysts are usually small, multiple, and often undetectable clinically, although they too contribute to the breast's nodular character. Usually they are noted only on gross or microscopic examination of the cut tissue. Occasionally, larger single cysts are encountered which are evident clinically as a lump, such as has already been described.

Although the contents of these cysts are serous, *they are under much pressure and are* firm; thus they may be mistaken for solid tumors, often imparting a hardness suspicious of carcinoma. The true diagnosis in such instances may be made by aspiration of the cyst or by operation. Occasionally the wall of a large cyst of this type presents a bluish, translucent appearance when exposed at operation; hence the term "blue dome cyst" given by Bloodgood. Aspiration of these cysts is usually curative. Carcinoma is rarely found in them.

A *galactocele*, or true retention cyst, due to a duct obstruction and containing retained milk is relatively rare and has little clinical significance because it usually empties spontaneously. If it does not empty, the contents will become inspissated; removal may then be indicated.

BENIGN NEOPLASMS

The breast area may be the site of neoplasms found in skin and subcutaneous tissue anywhere, such as lipoma, fibroma, and angioma. In the parenchyma, the most important benign tumor is the adenoma.

Intraductal Papilloma. Bleeding from the nipple justifies an immediate clinical diagnosis of intraductal papilloma; excision is necessary because of the possibility of malignant changes in this lesion. If the papilloma that is the source of the bleeding is palpable, it is excised locally. If no lump is palpable, the papilloma can often be located at operation by cutting down on a tiny probe inserted into the duct from which bloody fluid emerges or, at most, by removing merely the area of the breast from which the bleeding is expressed on pressure. In this way, sacrifice of the nipple and most of the breast is avoided. The papilloma should be submitted to frozen section (Fig. 6); if it is malignant, a radical excision is carried out. In a few patients, malignant disease will be detected only on paraffin section; in such an event, a second operation for removal of pectoral muscles and the axillary lymph nodes will be indicated.

Adenoma (Adenofibroma). Although the histologic appearance varies, this tumor usu-

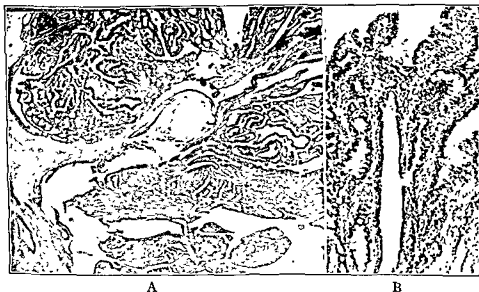


Fig. 6. Intraductal papilloma. The patient, a 37-year-old housewife, first noticed several months previously a discharge from the nipple which occasionally became blood-tinged but which never ceased. On examination a reddish discharge could be expressed from the nipple and a small tumor could be felt just below the areola. At operation the tumor was excised. A, photomicrograph showing a portion of the papillary growth as well as the stalk of the papilloma. The wall surrounding the tumor is only shown at the base of the stalk; it is probably the wall of a dilated duct rather than of a cyst. B, a high power view showing the character of the papillae and the hyperplasia of the cells. Despite this hyperplasia in this particular case no evidence of carcinoma was found in any part of several sections.

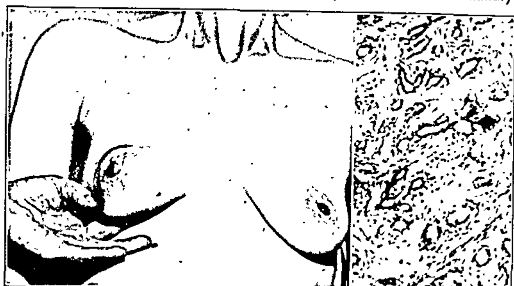


Fig. 7. Fibroadenoma. The patient was a 27-year-old woman. A lump had been noted two years previously; it had not increased in size but became slightly painful preceding each menstrual period. Note the lack of skin attachment although the tumor has been displaced by the examiner's fingers. At operation the tumor was not attached to the skin or parenchyma and shelled out very readily. Microscopic section of various parts of the tumor revealed features of adenoma, fibro-adenoma as well as of chronic cystic mastitis. The photomicrograph above shows this resemblance.

ally contains a much greater proportion of fibrous than epithelial elements. Indeed, the adenomatous tissue may be so slight as to form single layers of epithelial cells surrounded by great masses of connective tissue, thus giving rise to the term *intracanalicular fibroadenoma*. The fibromatous element may be diffuse connective tissue or hyaline periductile fibrous tissue, which is more elastic and translucent. Mucoid degeneration may occur, imparting to the tumor the designation of *adenomyxoma*. Other variations have been described. The epithelial cells resemble those lining the ducts although occasionally the acinous cells seem to give rise to the tumor. In any case, the tumor is clearly circumscribed and separated from the rest of the breast parenchyma by a loose layer of connective tissue, a characteristic which can often be detected clinically on palpation.

Clinical manifestations are not produced by an adenoma until a lump is discovered which is usually accidental. In most instances the mass is felt while the patient is bathing, or is noticed on examining her breast after some slight trauma. This latter fact accounts for the frequent belief on the part of many patients that the tumor followed an injury to the breast. Adenofibroma is largely a tumor of early adult life (Fig. 7) and is frequently encountered in young women and girls just after puberty. If the patient has known of the existence of the lump for a number of months or years, she may notice a definite, though slow, increase in size. Only rarely is the tumor multiple. Rapid growth may occur during lactation, due to the same stimulus which affects the rest of the breast; many women, indeed, first notice the lump during such a period. On examination, a firm encapsulated tumor is felt, which is quite distinct from the rest of the breast parenchyma. The mass is usually much larger and more definite than the lumps noted in chronic cystic mastitis, except when a single cyst is present. Perhaps the most diagnostic features of an adenofibroma are the smooth *rounded surface* and the extreme mobility, which at times is so pronounced that the tumor appears to "move" away from the examining fingers, with no more contact than a gentle touch.

Treatment always consists of surgical excision, just as in the case of any definite lump in the breast. While a lump may perhaps be observed for a time in the case of a young girl, surgical excision is practically always indicated in most women over 25 and in every woman over 35 years of age. The operation is quite simple and healing should take place with a relatively insignificant scar. Excision



Fig. 8. Sarcoma of the breast. The patient, aged 37, had known of the existence of a small tumor in the breast since the age of 13. For the past year it has been steadily and rapidly growing to its present size. At operation the tumor was found attached to the pectoral muscle. It is important to remember that such a tumor does not metastasize to the axillary lymph nodes and for this reason a simple mammectomy is sufficient. The prognosis is good. This tumor, originating in a fibroadenoma, is not to be confused with fibrosarcoma, which may also, though rarely, occur in the breast; its features have already been described.

enables a true diagnosis to be made, particularly if malignant disease is to be ruled out.

MALIGNANT NEOPLASMS

Mammary cancer is common and accounts for nearly 18 per cent of all deaths in women (8). Nearly all of these tumors are of epithelial cell *origin (carcinoma); sarcoma* (Fig. 8) comprises but 3 to 5 per cent of them. The female breast is predominantly affected (100:1). As with carcinoma elsewhere, advancing *age is the most predisposing* clinical factor, few cases occurring before the age of 35. After this age the incidence rises sharply, half of all cases being noted beyond the age of 50. The etiology of cancer of the breast is unknown, except for the possible role of sex hormones as shown by the greater virulence of the growth during pregnancy. Indeed, experimental cancer has been produced by repeated injections of estrin. The relation between skin irritation in Paget's disease and cancer is more definite; a detailed description of Paget's disease of the nipple will be found on page 877. Trauma and previous lactation have no proved etiologic connection with the disease, although cancer tends to grow quite rapidly when it occurs during lactation, due presumably to the *abundant blood supply.*

Pathology. A variety of types have been described arising from both duct and acinous epithelium. Classification is usually based on *the relative proportion of fibrous and* epithelial elements, the rapidity of growth, and particularly the microscopic arrangement of the cancer cells; especially their tendency to *form definite glandlike structures. In general,* three main types are described: medullary, scirrhus, and adenocarcinoma, but other lesser terms, such as comedocarcinoma and cancer cyst, *are also used to describe special* tumors.

Medullary (encephaloid) carcinoma or carcinoma simplex is a cellular and, in general, a rapidly growing *tumor which often,* however, exhibits periods of relatively slow progression. It is composed of an undifferentiated type of cell which does not form glandlike structures (Fig. 9), is rather *soft in* consistency, and occurs more often at an earlier age than the other types. The tumor



Fig. 9. Photomicrograph of a breast tumor showing medullary carcinoma. Note the invasive character of the growth.

is rather circumscribed and on cut section contains little scar tissue in contrast to the next type of tumor, scirrhus.

Scirrhus, as its name implies, is composed largely of fibrous tissue with a paucity of epithelial elements. Indeed, the predominance of scar tissue, which often seems to be engulfing the cancer cells, gives one the impression that the body is attempting to overcome and strangle the tumor. The large amount of fibrous tissue also gives the tumor its characteristic "stony-hard" sensation on palpation. It is just about as frequent as medullary cancer, but grows more slowly, metastasizes much later, and occurs more frequently in women of more advanced age.

Adenocarcinoma is so-called because its cells are arranged in the form of alveoli or acini. Many tumors of this group grow rapidly and metastasize widely within a year; others may be present for years before metastases occur. The tumor is more bulky than the scirrhus type, sometimes invades the skin and leads to extensive ulceration even before it spreads elsewhere. Colloid carcinoma is a form of adenocarcinoma in which much colloid material is present. It is rare and exhibits even a lower degree of malignancy than adenocarcinoma. Comedocancer is a descriptive term applied to tumors in which tiny bits of material may be squeezed from the cut surface of dilated ducts, many of which contain masses of tumor tissue. Cancer cyst is a term applied to a malignant tumor which, on cut section, is found to contain a cystic area due either to degenerative changes, to a dilated duct, or to an intracystic papilloma which has become malignant.

The *spread of cancer of the breast* occurs primarily by direct permeation into small lymphatic channels of the breast lobule (Fig. 10), into vascular channels, and into the subcutaneous tissue, fascia, muscle, and skin. When the tumor cells enter the skin lymphatics, they may be evident as small nodules just beneath the surface, giving to the skin an appearance similar to the studded breastplates carried by the knights of old, to which it owes its name, *en cuirasse*. This is often noted in the late stage of cancer, also in the skin as metastasis after removal of the cancer. Metastasis by way of the larger lymph channels occurs first to the regional axillary lymph nodes, occasionally the supraclavicular nodes, and to the internal mammary chain of the anterior mediastinum. Spread also takes place in a diffuse manner, particularly along fascial lymphatics which penetrate the pectoralis muscles and the chest wall, as well as the sheath of the upper end of the rectus. The internal mammary nodes are particularly apt to be the seat of metastasis if the tumor is located in the medial portion of the breast. Distant metastases occur by way of the blood stream, mainly to the liver and bony skeleton, particularly to the spine and long bones. It

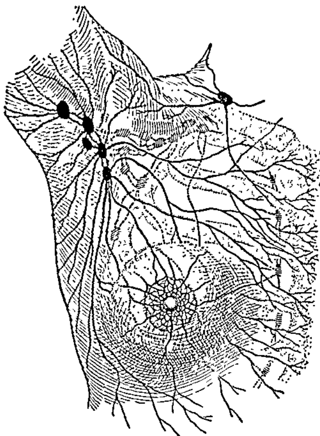


Fig. 10. The lymphatics of the mammary gland and the nodes into which they drain. (From Homans. Textbook of Surgery, Charles C Thomas.)

should be emphasized that vascular spread of the tumor cells is the mechanism responsible for the patient's death.

Clinical Manifestations. Since pain is seldom noted in early carcinoma of the breast, the first manifestation is usually a *lump* which is firm, poorly circumscribed and has a slightly nodular surface. Perhaps the most valuable single manifestation is *skin retraction*, which is present in about 80 to 85 per cent of cases and is often demonstrable only by shifting the tumor from side to side with the examining fingers (Fig. 11). It is caused by the cancer shortening the fibrous skeleton (Cooper's ligaments) just under the skin. When the tumor is extremely early, or located deep in the breast, this sign may be absent. Retraction of the skin over a malignant tumor is on rare occasions exhibited by three or four lesions which are not malignant. One of them is localized fat necrosis, which is described on page 880. The second is an abscess of subacute or chronic development due to infection with a pyogenic organism or to tuberculosis. Plasma cell mastitis occasionally results in skin retraction. A scar from a small laceration or incision may obviously result in retraction, but the presence of the scar will always identify the cause. When the tumor is located in or near the center of the breast, *retraction of the nipple* may be present (Figs. 12, 13). However, caution is urged in the use of this sign as an indication of cancer, because it is often congenital; when observed, the other nipple should be examined because congenital retraction is usually bilateral. Retraction of the nipple, to be of significance, must be of recent origin and unilateral, for in many women both nipples are always retracted. The *pig skin* or *orange peel* appearance of the skin over a tumor of the breast is another important, but later, clinical sign of cancer, often present together with retraction of the skin and like it made more prominent by relaxing

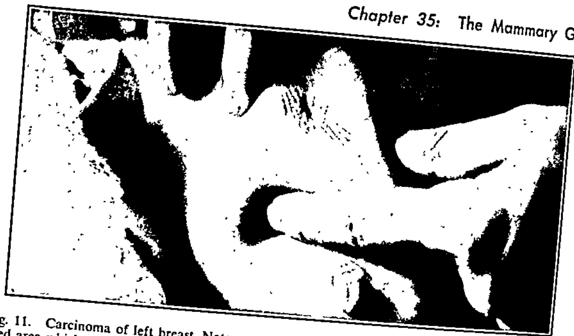


Fig. 11. Carcinoma of left breast. Note retraction of the skin. The lump lay directly beneath the retracted area which was firmly fixed to the tumor. The patient was 65 years old and first noted the lump three months previously. No axillary metastases were felt or discovered at operation. The tumor proved to be a fibrosing type of adenocarcinoma.

the skin over the tumor. This sign probably is produced by a depression of the openings of many sweat glands and hair follicles or by a local edema of the skin overlying the tumor (see Fig. 14). Edema may be present over an acute inflammatory tumor, but there is no difficulty in differentiating such an edema from that produced by cancer because of the lack of other signs of inflammation. Edema in cancer is unfortunately a late sign. Still later in the course of the disease, the tumor invades the overlying skin, and soon a necrotic ulcerating mass is formed. Regional *lymph node enlargement* in the axilla, or especially in the

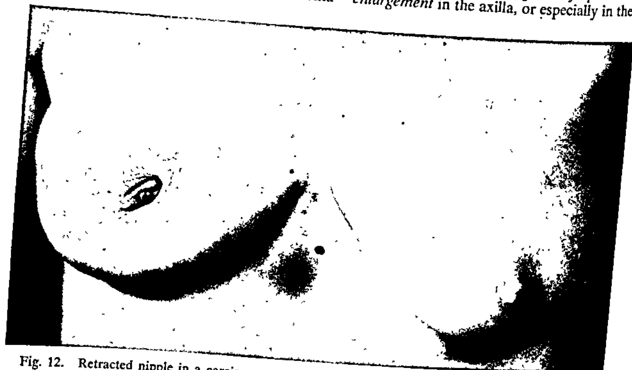


Fig. 12. Retracted nipple in a carcinoma of the breast. In this patient the tumor was located in the central portion of the breast but the mass measured only 2 cm. in diameter. (After Cole and Rossiter in Lewis Walter's System of Surgery, W. F. Prior.)



Fig. 13. Retraction of the nipple in carcinoma of the breast. In this patient the retraction is of a different type than that illustrated in Fig. 12, because the cancer has actually grown outward into the nipple. The mass is 5 cm. in diameter and occupies the entire thickness of the breast.

supraclavicular region, is another late manifestation of cancer in that it indicates metastasis, except when the enlargement is secondary to an infection, such as that associated with an ulcerating tumor. *Discharge from the nipple* occurs in slightly less than 5 per cent of patients with carcinoma. Since the discharge in carcinoma of the breast is bloody in only about half the cases (Hinchey) it is important to remember that the presence of a serous discharge does not eliminate the diagnosis of malignancy. The discharge is more apt to be bloody in intracystic papilloma, which is a frequent precursor of cancer, as already mentioned.

A diagnosis of cancer must be seriously considered whenever a single painless lump is noted in the breast of a woman past the age of 30 or 35 years. Operation is advised if for no other reason than to establish or rule out such a diagnosis. If the surgeon is not sure from his clinical examination that the tumor is benign, the patient should be prepared as if for radical operation rather than for local excision.

Treatment. At present the only hope of curing cancer is the total eradication of the malignant tissue by actual removal or by destruction *before it has spread* beyond range of such therapy. The former is achieved by surgical excision, the latter by radiotherapy (deep x-ray or radium). Adequate surgical excision is the procedure of choice in mammary cancer while in the operable stage.

The earlier mammary cancer is seen, the greater the clinical problem of deciding at the time of operation whether the tumor is benign or malignant. In such cases, the pa-

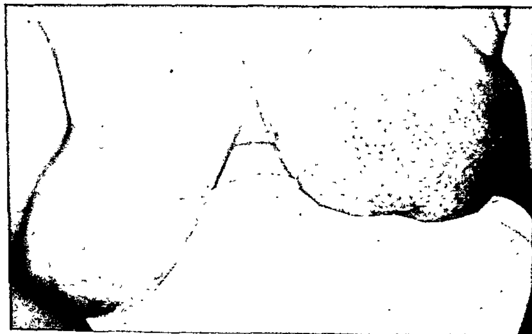


Fig. 14. Carcinoma of the breast with "orange peel" skin.

tient should be prepared as if for radical resection, and the tumor excised with a wide margin or normal tissue. This policy, unfortunately, has been used as a routine procedure. There has been an increasing tendency to subject all tumors to this procedure and await a diagnosis by frozen section before deciding on the type of operative procedure. Although such an approach is advisable and decisive in borderline cases, it should not be adopted as a routine method for several reasons. First, if the tumor is clinically malignant, cutting into it or around it is basically unsound. Second, the expense of frozen section can be saved in most cases if the surgeon himself performs a gross examination of the bisected tumor; he should be trained adequately to detect or exclude cancer in this way in the vast majority of cases. Third, the great fear of doing a radical resection for benign lesions (local inflammation and fat necrosis) is exaggerated because of the rarity of such lesions. Fourth, should competent gross examination prove equivocal, frozen section may also fail to reveal the true diagnosis. In such cases, permanent section will be necessary and a second operation can be carried out a few days later should the lesion prove to be malignant. Clinical follow-up studies in such two-stage procedures have apparently shown that they do not diminish the likelihood of a five-year survival if the biopsy has been *excisional* (Davis, 9). However, if it has been by aspiration or *incisional* biopsy several days before the radical operation, the probability of a five-year survival is sharply reduced.

The operation of choice in carcinoma of the breast, which has been adopted by most surgeons over the world, was first described independently in 1894 by Willie Meyer and W. S. Halsted. The nature of this procedure must be clearly understood and meticulously followed in studying the end results, which, indeed, have been shown to vary with the care with which this operation has been carried out. An *adequately* performed radical resection means a careful, sharp, and meticulous axillary dissection, denuding the axillary vessels, the chest wall, and the sheath of the latissimus dorsi all in one single specimen (en bloc). A wide area of skin around the tumor must also be removed. Just as important is extensive undermining of the skin flaps so as to excise sufficient subcutaneous tissue under them; this is necessary to ensure the inclusion of all mammary parenchyma which often extends widely under the skin beyond the breast itself. Wide excision of the skin often makes a skin graft essential (Fig. 15).

The importance of early operation in mammary cancer is shown by the excellent five-year survival rate following radical resection of the breast. For example, Harrington (10) reports a five-year survival rate of 51.2 per cent in 8,074 patients treated at the Mayo Clinic by radical resection; in this series, the five-year survival rate was 78.3 per cent in patients without axillary metastasis, and 32.5 per cent in patients with axillary metastasis.

It should be mentioned that a few clinicians, stimulated by the work and publications of McWhirter (11) over the past many years, believe that simple mastectomy and



Fig. 15. Skin graft following radical mastectomy. In 20 to 30 per cent of patients having a radical mastectomy for carcinoma a skin graft will be necessary. Operation was performed 10 days previous to this photograph. Note the site (almost healed) to the left of the umbilicus, where the graft was obtained. The graft should be performed at the time of radical mastectomy to shorten convalescence.

x-ray therapy to the axilla will yield just as good results as radical mastectomy. However, most clinicians strongly recommend radical mastectomy.

The problem of therapy in late, inoperable mammary cancer is a real one and should be based primarily upon the reduction of pain and other symptoms by any palliative means available. Radiotherapy (12, 13), particularly over metastatic bone involvement, is often effective for the relief of pain. In a few cases, such therapy is dramatically successful and may not only relieve symptoms but even prolong life. The use of testosterone, estrogen, and other hormones has also been extensively tried and in some instances is particularly effective (14, 15). Removal of, or radiation over, the ovary (16) has also been tried and is occasionally successful. More recently, bilateral adrenalectomy (17) and even hypophysectomy (18, 19) have been employed and, in a few cases, have led to dramatic regression and perhaps even disappearance of metastatic tumors. Why this occurs in some cases and not in others is unknown. Moreover, it is not known why the response, even in the most successful instances, is not sustained. In all such cases, even if temporary palliation is achieved, the tumor nearly always resumes its growth and the patient eventually succumbs.

Following radical mastectomy, slight to moderate *swelling of the arm and forearm* usually develops. Occasionally it is severe (even without recurrence of tumor in the axilla or mediastinum) and produces considerable disability. The excision of lymphatics is unquestionably related to the condition, but is not the sole causative factor. X-ray therapy and postoperative wound infection have been considered important in etiology, but practically all investigators studying this lesion do not find significant evidence of this relationship. In a study made by Fitts and associates (20), about the only significant factor found consistently was moderate obesity. The condition can be prevented to a great extent by wrapping the extremity with an elastic bandage for a few weeks, prophylactically or as soon as swelling appears. The patient should be instructed to sleep at night with the extremity elevated on a pillow. If swelling is allowed to exist over an extended period of time the edematous area becomes indurated (because of fibrosis) and then is very difficult to treat.

Some surgeons believe that the standard type of radical operation, as originally designed by Halsted, should be extended. For example Handley (21) and Urban (22) have recommended that when the cancer is located in the inner quadrant of the breast the internal mammary chain of lymph nodes should be removed with the breast along with a segment of the chest wall en bloc. Wangensteen (23) has recommended a super-radical operation in which, in addition to a radical breast operation, the sternum is split and the lymphatics in the mediastinum removed. More time will be required to determine the efficiency of these two procedures.

Paget's Disease of the Nipple. Paget's disease (Fig. 16) really consists of two lesions, a skin disease and a true carcinoma of the ducts of the breast. Since the skin lesion is observable first, carcinoma should be suspected whenever it is encountered. Most skin lesions of the nipple are benign and clear up in a few weeks with ordinary care, especially cleanliness. If the lesion is due to Paget's disease, it will not heal but will progress and finally lead to a destructive ulceration of the entire areola. A biopsy is justified in doubtful cases in order to establish the diagnosis.

In Paget's disease of the nipple, microscopic section shows an infiltration in the skin lesion of cells which are large and deeply staining, with sharp, round, vesicular nuclei and vacuolated cytoplasm (Fig. 16A). They are found under the epidermis and may extend outward, but remain in the superficial part of the lesion. It is believed by some observers that unless this peculiar cell (often called the "Paget cell") is present, a diagnosis of Paget's disease is unjustified. While this cell has a distinctly malignant appearance, it is entirely unlike the disease process present in the deeper tissues; the latter consists of a duct cell carcinoma arising in the terminal portions of the lactiferous ducts.

The *treatment* of Paget's disease of the nipple is the same as that for carcinoma of the breast, i.e., radical mastectomy. The prognosis is particularly good for patients without obvious metastases, since many of these tumors are slow to metastasize. However, if



Fig. 16A. Paget's disease of the nipple. This is a very early case in a 58-year-old woman. A tiny ulcer of the nipple, as shown in the photograph, first appeared four months previously; it healed at intervals, but always recurred. After operation several blocks of tissue were examined microscopically but no evidence of carcinoma was found, although the typical histologic picture of Paget's disease was noted in sections of the ulcer. This is shown in the low and high power photomicrograph as shown below the photo; note the characteristic appearance of the so-called "Paget cell."

the tumor has already extended and growth is active, the prognosis is no better than for any other case of carcinoma of the breast. Early removal of the lesion is, therefore, particularly important.

INFECTIONS

Inflammatory diseases of the mammary gland are similar to infections elsewhere, but a few are characteristic of the breast itself because of their location in the parenchyma of the organ.

Acute Mastitis. This lesion starts as an acute deep infection, usually of one portion of the breast, and may be accompanied by evidence of systemic invasion, such as a chill and fever. In most instances, the infected area rapidly softens and suppurates, forming an abscess of the breast. The organism is frequently the staphylococcus. Although it may occur in the nonlactating or virgin breast, acute mastitis is more common in pregnancy, particularly during lactation. Often the abscess is secondary to "caked breast" (p. 881). The infection probably enters through fissures or abrasions about the nipple and travels along the lymphatics of the ducts to the depths of the gland. Heat, redness, local pain, and tenderness rapidly develop; the pain is usually so severe that the patient seeks



Fig. 16B. Paget's disease of the nipple. In this patient, a woman of 59, a dermatitis of the nipple has been present for four years, and an eczematous ulceration of the areola for five months. A biopsy performed at "4 o'clock" where a crust is visible, revealed carcinoma. A radical resection was performed.

early relief. Less commonly, the lesion is deeply seated and reaches the surface more slowly or may penetrate beneath the breast and form a submammary abscess.

Treatment, such as cleanliness and protection of the nipple, will prevent fissures and abrasions and thus prevent infection by eliminating the portal of entry. Once the infection is present, the treatment is the same as that of acute inflammation elsewhere; early chemotherapy may prove rapidly curative and prevent suppuration. Otherwise heat, elevation, and rest are employed, followed by incision and drainage as soon as suppuration occurs. It is important that incision for drainage be made in a radial direction from the nipple in order to avoid cutting across the ducts. Incision must be carefully made, preferably under general anesthesia, and should be large enough to drain the cavity adequately. Since the abscess is apt to be multilocular, it is important to explore the ramifications of the cavity gently in order to insure complete drainage. Counter drainage is often necessary. The infection frequently burrows extensively, thereby accounting for its tendency to form a chronic draining sinus because of inadequate drainage or the presence of necrotic tissue. If the abscess is submammary, a more lateral circular incision may have to be made. In view of the increased resistance of the staphylococcus to penicillin, selective chemotherapy by isolating the organism and testing it for sensitivity may be essential in the refractory cases.

Chronic Mastitis. A chronic draining sinus, which may be multiple, is usually the result of an inadequately drained abscess of the breast; a history of the acute process is often obtained. However, the possibility of tuberculosis or fat necrosis should always be considered, particularly from the history; it is often ruled out only by microscopic examination of excised tissue. If the lesion is actually due to a pyogenic infection, heat, selective chemotherapy, elevation, and more efficient drainage may result in healing. Often, however, especially in the neglected cases, the destruction of tissue has been so great that total mammectomy may be indicated.

Tuberculosis. Tuberculosis of the breast, though rare, may be difficult to diagnose even if it is merely secondary to disease elsewhere. The usual history is that of a painless lump of long duration which finally suppurates, opens, and results in one or more sinuses

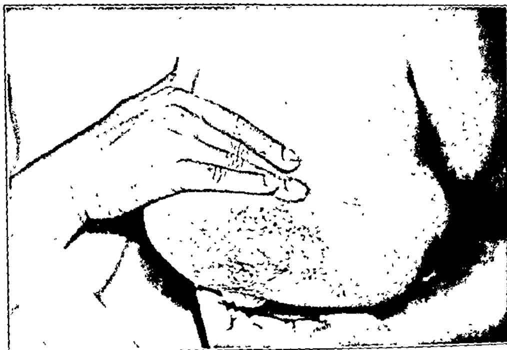


Fig. 17. Tuberculosis of the breast. Note the ulcers which are the sites of draining sinuses which open and close at intervals. The patient, aged 40, had known of a lump for many years. Several years previously it became painful, was incised, and pus obtained. A second abscess appeared recently; pus was aspirated, showing no organisms on smear or culture, and gave an equivocal guinea-pig test (the animal died too soon). The diagnosis is based on the presence of tuberculosis elsewhere (lungs, tarsus). Excision of the breast with the diseased tissue has been advised; definite identification of the lesion can be established only by this means, or biopsy (aside from the tests already mentioned).

which fail to heal (Fig. 17). If the pus is obtained before secondary infection has occurred, the organism may be found on smear; injection of pus into guinea pigs should reproduce the disease. Otherwise, biopsy of the diseased tissue is the only certain method of diagnosis. Treatment consists of excision of the diseased breast and the use of streptomycin and associated ancillary drugs.

MISCELLANEOUS LESIONS

Injury. Trauma to the mammary gland is rare and poses no special problem in diagnosis or treatment except when a swelling is noticed thereafter. In most instances, the association is a coincidence, the lump having been present previously but overlooked until the trauma caused the patient to palpate her breast. In some cases, a true hematoma may be the cause of such a swelling; in a few instances, the swelling may be due to fat necrosis.

Fat Necrosis. This lesion produces a firm, palpable mass, frequently with skin retractions and is, therefore, easily mistaken for carcinoma. There will be a history of trauma preceding the development of the lesion in 30 to 40 per cent of cases; accordingly, the lesion is often spoken of as traumatic fat necrosis. Early in the course of the disease, the mass is soft, but as fibrosis develops it becomes harder. "Orange peel" skin and retraction of the nipple rarely occur. Enlarged nodes are often encountered in the axilla but they are not as hard as metastatic nodes from a carcinoma. Occasionally sinuses develop, often following incision of a soft fluctuant area erroneously thought to be an abscess. The diagnosis is usually made only after excision, upon bisecting the tumor. The presence of an irregular mass of slightly reddened tissue containing liquid fat, is characteristic. The microscopic section shows deposition of scar tissue and round cell infiltration, besides the necrotic fat. It has no relation to cancer.

Treatment is surgical, primarily because carcinoma cannot be excluded. The mass should be excised widely, including skin if attached, and the specimen submitted to frozen section. However, the diagnosis is usu-

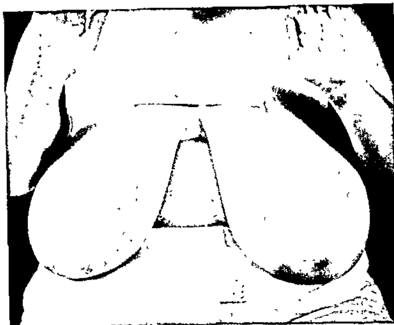


Fig. 18. Simple hypertrophy of both breasts. This patient was 35 years old and had developed a gradual enlargement of both breasts beginning 10 years previously.

ally made readily on gross examination because of the presence of areas of necrosis and liquefaction of fat, without the grayish granular surface so typically seen in carcinoma.

"Caked Breast." At any time during lactation, one segment of the breast may become hard and somewhat tender, but without other signs of inflammation. The lesion is rather common and is generally called "caked breast." It usually subsides spontaneously but may give rise to suppuration. The pathogenesis of the lesion is somewhat in dispute, but obstruction of the involved secreting parenchyma is generally considered to be an important factor. In addition to the local retention of milk, which produces an entirely different picture from a galactocele, infection is also supposed to play a role. The entrance of organisms of low virulence through the nipple is supposed to result in a local but mild type of mastitis, similar in nature to acute mastitis which has already been described. *Treatment* is directed toward relief of the lesion in order to minimize the danger of suppuration. A supporting bandage is usually sufficient, but gentle massage and the use of the breast pump may also be indicated. When there is evidence of infection, treatment is carried out as described elsewhere.

Simple Hypertrophy. Enlargement of the breast, starting in the female at puberty, ordinarily ceases when the breast has reached a moderate size. Occasionally, the growth stimulus continues until the breasts are greatly enlarged and interfere seriously with the comfort and even the health of the patient. On other occasions, the hypertrophy does not develop until several years after puberty (Fig. 18). The etiology is poorly understood, but is presumably related to endocrine dysfunction. Pain in the shoulders and neck is common, caused presumably by the excess weight of the breasts. If supporting bandages do not give relief, a plastic operation with partial amputation of the breasts may be necessary; results following this procedure are very good.

Premature (precocious) enlargement, usually of one breast, is rare but is seen occasionally in young girls before puberty and is presumably due to precocious endocrine stimulus. There is often a history of trauma which brings the patient to the doctor; occasionally severe spontaneous pain occurs (puberty mastitis). The enlargement is rarely pronounced and causes no difficulty because of its size. Recognition of the nature of the swelling will enable a true diagnosis. Reassurance

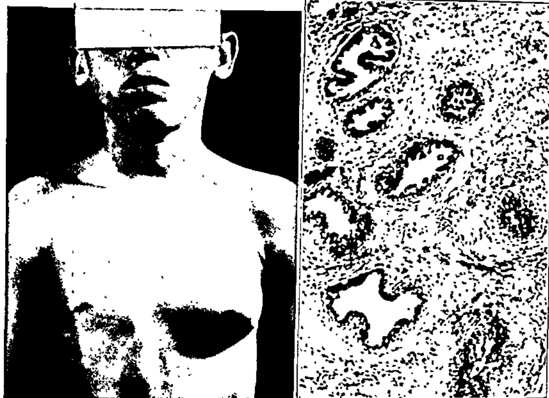


Fig. 19. Gynecomastia affecting the left breast. The photo is of a boy 14 years old. The swelling of the breast was first noted one year previously; slight pain and tenderness were present. The photomicrograph on the right is from another patient but is typical for this lesion. There is mild hyperplasia and lymphocytic infiltration.

is usually all that is necessary. Complete surgical excision is obviously contraindicated; with the advent of puberty both breasts develop symmetrically, in most instances. In young boys, however, a similar phenomenon requires excision (see Gynecomastia).

Mastodynia. This ill-defined term applies to pain in the breast which is often of severe and disabling character. As already mentioned, this symptom is nearly always due to an associated chronic cystic mastitis. Occasionally, however, palpation of the breast reveals little or no abnormality. Such cases have been called neuralgia of the breast and may be similar to other true neuralgias (see Chap. 27). Psychogenic factors probably play an important part. Treatment is often unsatisfactory; mammectomy may be justified occasionally, especially in women past the childbearing period, but even this may be unsuccessful in the relief of pain.

Gynecomastia. Enlargement of the mammary gland in the male is called gynecomastia (Fig. 19) and is caused by an endocrine dysfunction, often by an increased output of estrogen or diminished production of testosterone; it is most commonly observed shortly after puberty. When both breasts are involved, tumors of the testicle (less commonly of the adrenals or pituitary gland) may be the causative factor. Occasionally the enlargement is due to inflammatory changes of a chronic type or to a cystic disease somewhat similar microscopically to chronic cystic mastitis in the female. Symptoms may be absent or consist of slight pain or discomfort. The unilateral tumors should be excised even if small in size, particularly because of the danger of cancer, which does occur occasionally in the male breast. If cancer is present, clinically or microscopically, a radical resection should be carried out. In young boys, gynecomastia may be a psychogenic problem and requires simple excision, with preservation of the nipple for cosmetic reasons. In bilateral gynecomastia, endocrine therapy with

testosterone reduces the hypertrophy, but recurrence takes place when the therapy is stopped.

Aberrant and Accessory Breast. These congenital anomalies are rare and usually produce few clinical manifestations.

The aberrant breast is a misplaced portion of normal parenchyma, located usually in the anterior axillary fold; unlike the accessory breast it is not associated with a separate nipple. It is usually mistaken for a benign tumor; excision may be indicated, particularly if carcinoma is suspected.

Accessory breasts usually consist merely of a more or less well-developed nipple without any secreting tissue. They occur along the "*milk-line*" *which extends from the axillary* to the inguinal fold. Simple excision is sometimes indicated, usually for psychic reasons only.

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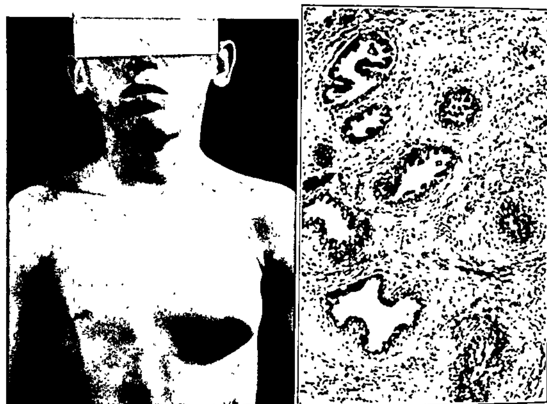


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36

SURGICAL DISEASES OF THE THORAX

Thomas H. Burford and Thomas B. Ferguson

Thoracic surgery has grown remarkably in scope and effectiveness during the past two decades. In this chapter, consideration is given to those conditions of the thorax which are of interest to the surgeon exclusive of the esophagus and the heart, pericardium, and great vessels.

THORACIC CAGE

Malformations. Many of the malformations are of no surgical importance because they produce no symptoms. There are some, however, which deserve attention. Occasionally there is a complete or partial absence of the anterior thoracic wall which may be associated with ectopia cordis. The overlying skin in such cases may or may not be absent. Sometimes this condition is severe enough to necessitate a plastic repair but it is, after all, rather rare. Another condition, known as funnel chest (pectus excavatum), occurs, in which there is a more or less marked depression and concavity of the sternum. In most cases, this condition is accompanied by no symptoms, but occasionally serious pressure effects on the heart and great vessels, the esophagus, and even the liver may occur. This deformity is not always congenital but may result from trauma. Surgical correction has been recommended both for decompression of the mediastinum and for cosmetic reasons. The operation consists of resection of the deformed costal cartilages and elevation and fixation of the sternal plate. Results of the procedure are generally excellent.

Fractures and Dislocations of the Sternum. These lesions are occurring with increasing frequency as a result of vehicular accidents. In simple sternal fractures or dislocations with displacement, early open reduction with wire fixation yields the best results. Sternal injuries associated with the "crushed chest" syndrome will require immediate temporary stabilization with balanced traction or some other effective expedient to assure proper aeration of the lungs.

Inflammations of the Chest Wall. Inflammations of the chest wall, in a few respects, have characteristics which distinguish them somewhat from inflammations of other parts of the surface of the body. Of the ordinary pyogenic infections *subpectoral* abscess and *subscapular* abscess are both worthy of special mention. The former arises from an infection which begins in the loose areolar tissue beneath the free border of the pectoralis major or minor muscles. It is sometimes secondary to an infection of the axillary lymphatics or to an abscess of the breast. When a swelling is apparent, it is found under the outer border of the pectoralis major muscle. In many cases, only a fullness is made out in that region without any local redness of the skin. Adduction and outward rotation of the arm are especially painful; but in the severe cases any movement of the arm is painful. The constitutional symptoms are often very marked. The lesion is often overlooked and it is necessary, therefore, to bear the possibility of it in mind in connection with infec-

tions of the hand, arm, or breast in which the constitutional effects persist after local drainage seems to have been adequately established. The treatment of the condition is to establish free drainage. For this purpose it is usually necessary to make an ample incision along the external border of the pectoralis major muscle and usually it is necessary to divide some of the fibers of that muscle. Chemotherapy may be used with surgery as discussed elsewhere.

Subscapular abscess is more rare than *subpectoral abscess*. It is often mistaken for a tumor of the chest wall, partciularly of the scapula. Even when the abscess is produced by pyogenic organisms there may be practically no local evidences of inflammation except fluctuation. Few of these cases are tuberculous in nature. Ample drainage is imperative.

Osteomyelitis of the Sternum and Ribs. Osteomyelitis of the sternum, though rare, was frequently fatal before the development of antibiotic therapy. It is now seldom seen, and the mortality is much lower than formerly. Primary osteomyelitis of the ribs is also rare but it occurs often enough to deserve some attention. When it occurs, the best treatment is removal of the infected portion of the rib. Prompt recovery ordinarily follows this procedure. Secondary osteomyelitis is rather frequent, especially after operations for drainage of an empyema cavity at which a portion of a rib has been resected. In the great majority of cases, healing occurs without any marked symptoms, but sometimes small sequestra get into the abscess cavity and result in the establishment of a chronic fistula which runs the course of a typical foreign body infection with closure for a few weeks at a time followed by a recurrence of signs of local inflammation and a reopening of the fistula with the discharge of pus In such cases, it is often necessary to resect the involved portions of the rib.

Tuberculosis of the Sternum and Ribs. Tuberculosis is the most common inflammatory disease of the ribs and sternum except for those which follow compound fractures. It occurs most frequently in middle life and almost always originates with rupture of a tuberculous lymph node in the mediastinum. Frequently, an abscess will travel a long distance to open spontaneously. It seldom discharges into the pleura. Like cold abscesses elsewhere, the local evidences of inflammation are usually not marked. Frequently, the first feature noticed by the patient is a soft swelling which fluctuates but is not red. If the swelling is aspirated, the characteristic curdy pus will be obtained. If a sinus is already present, necrotic bone can sometimes be felt with a probe. An x-ray examination, particularly after the injection of lipiodol into the sinus, is often helpful in making a diagnosis. If the disease is confined to a single rib its wide removal frequently results in satisfactory and complete healing. Heliotherapy and hygienic treatment are of great value as supplementary aids. If a costal cartilage is involved, it is necessary to remove the entire cartilage. Streptomycin used in conjunction with surgery has resulted in a very greatly improved outlook for the patient with a tuberculous sinus.

Syphilis and actinomycosis of the bony chest wall occur but will not be given any special consideration here because of their comparative rarity.

Tumors of the Chest Wall. Nearly all of the common benign tumors have been recognized as arising in the chest wall. The most important tumors, however, are those which arise from the bones. Simple osteomas have been described but nearly always cartilage is also present and, therefore, for the most part such tumors are really enchondromas. A large proportion of them are malignant. This is particularly true of the cartilaginous tumors which arise from the costal cartilages. Occasionally they arise in the scapula. They often become of enormous size even when they are benign, and the symptoms which they produce, for the most part, are those of pressure against other structures and visible deformities. They are usually hard, rounded, and lobulated but frequently, in parts of the tumor, softening occurs from mucoid degeneration. Although they are slow to metastasize, they show a marked tendency to recur after extirpation (Fig. 1). The most difficult features of the diagnosis are the determination of the extent of the tumor and of whether or not it is malignant. Even when suspected of being benign and of limited extent the extirpation of these tumors should never be

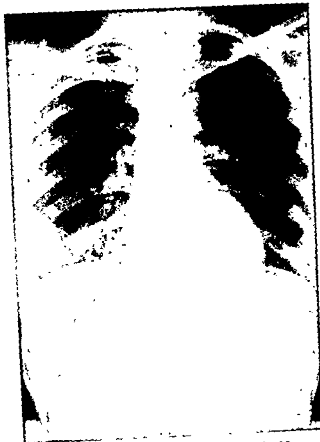


Fig. 1. Chondrosarcoma of rib. This 28-year-old woman complained of pain in the right lower chest. Biopsy of the mass revealed chondrosarcoma. Metastatic lesions are already present in the left lung. The patient went downhill rapidly and expired.

undertaken lightly because it is often necessary to remove large portions of the chest wall in order to get completely around the neoplastic tissue. The most frequent malignant tumor arising in the chest wall is a sarcoma. Practically all varieties of sarcoma have been observed in this region. It is noteworthy that many cases in which a diagnosis of simple chondroma has been made were subsequently proven to be sarcomas. In a series of 213 cases of tumors of the bony chest wall analyzed by Hedblom, 131 were sarcomas. The usual origin is in the ribs. Carcinoma of the chest wall, exclusive of that which arises in the mammary gland or in the skin, is never primary.

Injuries of the Thorax. For convenience, the injuries of the thorax are usually classified as: (*a*) nonpenetrating and (*b*) penetrating.

NONPENETRATING INJURIES. These are of importance chiefly because of the injury which may occur to important intrathoracic structures without any external evidence that such injuries have occurred. It is very common to find fractures of the bony cage without external evidence of injury to the skin. It is still more important, however, to realize that extensive injury of the intrathoracic viscera may occur without any fracture of the bony chest wall. Such a possibility is particularly prevalent in the elastic resilient thorax of a baby or a young child. There are three complications which deserve particular attention and should always be considered. These are intrathoracic hemorrhage, a dangerous degree of tension pneumothorax, and mediastinal emphysema. If a picture of shock occurs an hour or more after the injury, the possibility of *intrathoracic hemorrhage* should be strongly considered. In lacerations of the lung, hemoptysis usually, but not always, occurs. But intrapleural hemorrhage can occur from other vessels than those in the lungs, particularly intercostal arteries, the internal mammary artery, and so forth. Pneumothorax may occur alone or in association with a collection of blood. If the pneumothorax comes from a type of injury to the bronchial tree which permits the entrance of air into the pleural space but prevents its exit, very alarming symptoms of dyspnea may occur. This condition of *tension pneumothorax* requires prompt aspiration of the contained air in order to save the patient's life. *Mediastinal emphysema* usually occurs after a laceration of the trachea or of a main bronchus. It is not so likely to occur after a simple laceration of the lung. The air may travel from the mediastinum throughout the entire body. In a severe example of this sort all of the subcutaneous tissues may crackle, even as far down as the feet, and marked swelling of the face is present. Another complication is a laceration of the diaphragm which permits abdominal viscera to enter the thorax. The existence of this complication may not be recognized until some years later. Massive atelectasis also occasionally occurs. A severe type of nonpenetrating injury is seen as the result of a crushing injury in which much of one side of the chest wall may be pushed into the thoracic cavity. It is, of course, associated with multiple fractures of the ribs and, usually, extensive intrathoracic complications.



Fig. 2. Decortication of the lung. This patient had a hemothorax treated ineffectively with recurrent thoracentesis. Left, shows the air-fluid level, and the thick membrane which is preventing the lung from expanding. Right, shows the resulting expansion obtained by thoracotomy and removal of the limiting membrane.

In the treatment of nonpenetrating injuries of the thorax, consideration must first be given to the immediate care of shock and to a careful examination of the patient for any evidence of injury to viscera, thoracic, abdominal, or brain, and to the presence of multiple fractures. If, after a blood transfusion for the treatment of shock, a patient's condition improves and then grows worse again, the question of a continuing intrapleural hemorrhage should be strongly considered with the idea of opening the thorax *to find the bleeding vessel. It is not wise to* provide open drainage for a hemothorax because of the infection which will inevitably result.

Experience in World War II showed clotting of blood within the pleural cavity to be more frequent than heretofore suspected. If blood accumulates in the pleural cavity at the time of injury and is not removed, it will clot and produce a thick limiting membrane preventing expansion of the lung (1) (Fig. 2). Accordingly, effort should be made to remove blood early after injury to prevent clotting. When discovered later, the pleural cavity will have to be opened, the clot removed, and the lung decorticated of the restraining fibrinofibrous membrane. The ideal time for operation is three to five weeks after injury.

Costal fractures should rarely, if ever, be strapped with adhesive tape. Intercostal nerve block with procaine posterior to the fracture sites is a much more efficient and physiologic procedure. A flail chest resulting from anterior and posterior fractures of the same rib or ribs will, however, very frequently be stabilized by pressure strapping.

By eradicating pain, mobilizing the chest wall, and thus re-establishing an efficient breathing and coughing mechanism, intercostal nerve block will do much to prevent *massive atelectasis. If massive atelectasis de-*velops, it should be actively treated at once. If turning the patient with the involved side up and vigorous coughing do not reaerate the lung promptly, bronchoscopy should be done. For the patient who cannot or will not raise tracheobronchial secretions adequately, the method of tracheobronchial catheter aspiration as described by Haight (2) is frequently lifesaving. The patient with a severe thoracic injury should have a tracheostomy to reduce the work of breathing and the dead space and to facilitate the removal of the copious secretions (3).

If there is evidence of injury to any of the abdominal viscera or to the brain they should be treated in accordance with the indications present.

Penetrating Wounds of the Chest. Penetrating wounds differ from those which are nonpenetrating chiefly in the fact that the former are more likely to be associated with infection. In addition, the element of open pneumothorax is likely to be added which, in itself, may be a very serious complication. Infection caused by penetrating wounds is often due not only to the direct introduction of pathogenic bacteria but also to the retention of a foreign body in the thoracic viscera with more or less destruction of tissue by the missile. All of the complications already mentioned for nonpenetrating injuries can occur after those which penetrate. The experiences in World War I and World War II showed that the first and most important indication is to close a sucking wound of the chest after débridement of the edges. This procedure avoids the serious mechanical consequences of an open pneumothorax. Closure of a sucking wound is indeed an important first-aid procedure and should be achieved by means of a firm occluding bandage. If a frank empyema develops, it should be treated by adequate drainage as in the case of an empyema which arises as a complication of pneumonia. At all times after the wound is closed, the patient should be carefully watched for the possible development of serious pressure effects from entrapped air under pressure or from too much fluid in the chest. Small missiles, such as rifle or pistol bullets, are usually comparatively innocuous even when retained in the lung. Large, jagged fragments of metal, however, ordinarily should be removed and if there is positive evidence of retained particles of clothing which have been carried into the thorax, these should also be removed. Under no circumstances should indiscriminate probing of the wound be carried out. Metallic foreign bodies can almost always be accurately localized with the x-ray. Splinters of bone driven into the lung may cause trouble later by being the focus of one or more pulmonary abscesses. If the fragments of bone are large enough to be detected with the x-ray it is usually better to remove them than to wait for an abscess to develop. Under no circumstances, however, should a thoracotomy be performed for the removal of foreign material until after the patient has recovered from initial shock following the injury. Various special technics were devised during both World Wars for the removal of retained projectiles in the chest. Special and more comprehensive works on thoracic surgery should be consulted for a description.

Hernia of the Lung. This condition is rare and will not be extensively considered. Occasionally, it is encountered as a congenital defect but more often it follows an injury of a sort which has permitted the lung to escape through an intercostal space. When the hernia is of any size it should be repaired by a plastic operation on the chest wall.

DISEASES OF THE PLEURA

Acute Empyema. The most important surgical condition of the pleura is empyema, more properly designated as *empyema thoracis*. This is a condition in which pus is present in the pleural cavity and it is, therefore, an abscess of the pleura. It is most important to distinguish this condition from a collection of serous or serohemorrhagic fluid.

With the advent of penicillin there occurred a very marked reduction in the incidence of empyema following all types of pneumonia. Today an established thoracic surgeon may not see a case of empyema for an entire year. Similarly, in those that do occur the process is less acute and less damaging to the patient. Unfortunately, this attenuation often leads to bizarre loculations and other features which may make the empyema more difficult to diagnose and manage.

Technical improvements in pulmonary surgery as well as the antibiotics have markedly reduced the incidence of empyema following thoracic operations and trauma.

Empyema (suppurative pleurisy) is most often due to one of the pyogenic organisms. Tuberculous empyema is common and even such conditions as actinomycosis, streptothricosis, and blastomycosis may be associated with an empyema caused by those specific organisms. It is practically always a complication of some type of pneumonia except when it occurs as the result of a penetrating wound of the thorax or, more rarely, by spreading upward into the thoracic cavity of an abscess beneath the diaphragm. The type of pneumonia which precedes the development of the empyema may be different in different cases. For example,

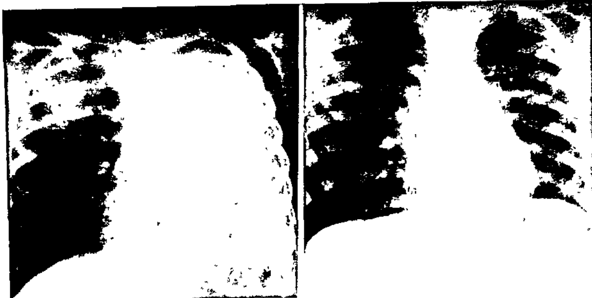


Fig. 3. Treatment of early empyema of childhood by closed drainage. This seven-year-old boy developed extensive staphylococcal pneumonia following the chicken pox. Left, shows the pneumonitic infiltration bilaterally with pleural fluid on the left. Thoracentesis revealed cloudy yellow fluid which contained staphylococci on smear. He was treated with closed catheter drainage of the pleural space and antibiotics. Right, shows the chest after recovery. There are a few pneumatocoeles in the left upper lobe, a characteristic for this disease.

when due to a pneumococcus, the empyema usually is a sequel of a lobar pneumonia; when due to a streptococcus, it is most often a complication of a bronchopneumonia; when caused by other pyogenic bacteria, it is usually a complication of some type of suppurative inflammation of the lung, such as pulmonary abscess or bronchiectasis. The pneumococcal and streptococcal varieties are more common in children than in adults.

Staphylococcal empyema in children requires special mention. Since the pneumonitis is usually associated with multiple small peripheral abscesses which may rupture with the development of a pyopneumothorax, it is mandatory to institute closed catheter drainage of the pleural space just as soon as the effusion appears and staphylococci are identified (Fig. 3).

Symptoms and Diagnosis. A suspicion of the presence of an empyema should always be aroused in any case of lobar pneumonia if the temperature comes down to normal for a day or two and then begins to rise. Formerly, many cases which illustrated this phenomenon were diagnosed as unresolved pneumonia. It is now, however, generally recognized that unresolved pneumonia is a comparatively rare condition and that nearly all cases which were formerly given that diagnosis are, in reality, examples of empyema. In not all cases of postpneumonic empyema does the temperature come down to normal before the empyema begins, but in the majority of pneumococcal infections such a phenomenon occurs. In the streptococcal cases, this tendency is less evident. In any case of inflammation of the lung in which there is a sudden increase in the temperature with greater prostration of the patient, the beginning of empyema should be suspected. It is not always easy to be certain in such a case whether the increase in temperature is due to a spread of the pneumonia or to the beginning of empyema. Evidence of a fresh involvement of the other lung is some indication that the condition is really a spread of the pneumonia. The ultimate diagnosis of an empyema, however, will depend upon an exploratory aspiration. Pain and tenderness are rarely present unless the chest wall itself is invaded. If the empyema has been produced by the spontaneous rupture of a pulmonary abscess, the signs and symptoms are usually much aggravated and often there will be air as well as fluid in the pleural cavity which may be recognized on an

x-ray examination if the patient is placed in a suitable position to show a fluid level, i.e., with the x-ray tube so placed that its rays are directed through the body in a horizontal direction. Such a condition is often spoken of as *pyopneumothorax*.

The physical signs of an ordinary acute empyema are practically those which are found in connection with any collection of fluid in the pleural cavity. Occasionally, in the acute cases if the effusion is large and if it has come on rapidly, the affected side may show a bulging. More often, however, the affected side appears smaller and flatter than the other because of nature's attempt to immobilize that side of the chest. In the early cases, there may be a marked displacement of the mediastinal contents to the healthy side. In long-standing cases, however, the displacement of the mediastinum may be toward the affected side. In the acute streptococcal cases, there may be extreme dyspnea and cyanosis because of the concomitant presence of extensive bilateral pneumonia. In the ordinary postpneumonic pneumococcal cases, dyspnea and cyanosis are not extreme. In cases of encysted emypema, the physical signs usually vary from those elicited when the empyema has originated in the free pleural cavity. In interlobar empyema, the physical signs are often confusing and may be mistaken for a pulmonary abscess. In most cases of the latter type, bronchial fistulas are present and therefore a fluid level with gas above it may be seen on an x-ray examination occupying the ordinary position of an interlobar fissure. Otherwise, the x-ray examination in cases of empyema is not usually distinctive from the findings present in any pleural effusion.

The constitutional disturbances are essentially the same as with any other acute infection. In children, the temperature is usually high (40° C. or 104° F.). As the empyema becomes more chronic, however, the temperature, which is of the septic type with remissions, generally has a lower daily maximum. A rather high polymorphonuclear leukocytosis is nearly always present. Clubbing of the fingers and toes is often seen in the subacute and chronic cases.

The systemic symptoms caused by empyema may be masked completely by prior or present antibiotic therapy.

COMPLICATIONS. The most common complications of empyema are bronchial fistula, perforation of the thoracic wall (empyema necessitatis), suppurative pericarditis, peritonitis, blood-stream infection, bilateral empyema, mediastinal abscess, and various miscellaneous complications such as meningitis, brain abscess, and multiple arthritis. The pneumococcal cases are much less likely to be complicated by other lesions than are the streptococcal cases. In listing the complications as has been done here, the opinion is implied that empyema is a complication of pneumonia rather than that pneumonia is a complication of empyema. Likewise, when the empyema occurs in association with one of the acute exanthemata, it is a sequel to the pneumonia which has complicated the main disease.

TREATMENT OF ACUTE EMPYEMA. In the treatment of every case of acute empyema there are two fundamental considerations. One is to save life and the other is to prevent chronicity. It is unfortunate that the treatment of acute empyema has been clouded by strong advocacy of various detailed methods. In its true sense, empyema is an abscess of the pleural cavity. When an abscess is present in that locality it should be treated like abscesses in other parts of the body, namely, by drainage. Much of the confusion in the literature about the treatment of empyema has arisen because a clear and precise discrimination has not been made between a fully developed abscess and one in its formative stage. In other parts of the body, drainage of infections which are destined to become abscesses is not considered until the abscess has actually developed to maturity. Experience has clearly shown that premature drainage of such infections is very likely to be accompanied by disastrous results to the patient.

In the case of infections of the pleural cavity a particular situation exists which makes it increasingly dangerous to establish wide free drainage before a definite abscess has been formed. The special reasons which obtain in the case of acute infections of the pleural cavity are concerned with the special physiology of the region involved. Since res-

piration is dependent upon the creation of a negative pressure in the thorax, at least at some time in the act of inspiration, it is apparent that any opening into a free pleural cavity is likely to result not only in embarrassment of the respiration but also of the circulation to some extent because of the dependence of the filling of the auricles of the heart upon a negative pressure. During the formative period of an empyema the danger of interference with the normal intrathoracic pressure relationship is particularly great because at such time the patient is usually suffering from a more or less extensive pneumonia and a consequent marked reduction in his vital capacity. If the patient is already cyanotic and orthopneic, his vital capacity may be so low that it may approach the tidal air requirements. In other words, under such conditions, in spite of maximal inspiratory effort, the patient can take in scarcely more than enough air needed to carry on life, even at rest in bed. There is, therefore, practically no reserve upon which he can draw to compensate for any further embarrassment of his respiration. Even a very small opening of the pleural cavity under such circumstances may be fatal because the effect of any opening in the pleural cavity is not confined to the lung of one side unless it is adherent to the chest wall or unless the mediastinal tissues are sufficiently stabilized by inflammatory thickening to prevent a shift of the mediastinum to the opposite side. On the other hand, a person with a normal thorax can withstand a much larger opening in his pleural cavity because he can compensate for the larger opening by drawing upon his respiratory reserve. In other words, in a thorax in which there are no adhesions and no stabilization of the mediastinum, the size of the pleural opening which can be withstood by the patient depends largely upon that individual's vital capacity. During the formative period of an acute empyema there is not much stabilization of the mediastinum, and any adhesions which have formed are still delicate and easily broken, with the result that the creation of an open pneumothorax by establishing a free open drainage is equivalent to doing that in a thorax which has no protection against it. If, therefore, the vital capacity is very low because of the presence of an extensive pneumonia, such an individual may die promptly of asphyxia if a free opening is made into his pleural cavity which is allowed to communicate with the outside air. On the other hand, if the infection has developed into a definite abscess and has become an empyema in the true sense, an opening for drainage is accompanied by practically no respiratory disturbance. This absence of deleterious result is because of several features. One is that under such circumstances the opening is made into an abscess rather than into the free pleural cavity. There are, therefore, no serious pressure effects on either one or both lungs. Moreover, it happens that an empyema seldom becomes a true abscess until after the pneumonia has cleared to a considerable extent. The patient's vital capacity is, therefore, higher and even if there were pressure effects they would be of less consequence because the patient would be more able to withstand them.

In view of the foregoing remarks, it should be evident that the creation of an open pneumothorax by the establishment of free open drainage should never be undertaken unless definite frank pus has been demonstrated by aspiration (Fig. 4). Experience has indicated that when definite frank pus is present there is no ascertainable difference in the results whether one uses an open drainage at that time or some method of drainage which will exclude the influence of the outside air. The principle involved in the latter method is known as closed drainage. The obvious and most important conclusion to be drawn doubtless is that patients are not very likely to die of acute empyema itself. Many will die, however, from an injudicious operation if the surgeon *creates an open pneumothorax during the formative period of the empyema.* The two most important principles to bear in mind are: 1. not to create an open pneumothorax during the time when pneumonia is present; and 2. to provide adequate drainage when it has been decided that drainage is necessary. A third principle is to successfully maintain the nutrition of the patient. If, in a given case, an aspiration (thoracentesis) reveals only turbid fluid, it is very unwise to create an open drainage. Instead, the patient should be treated either by aspiration as often as seems necessary to relieve serious pressure

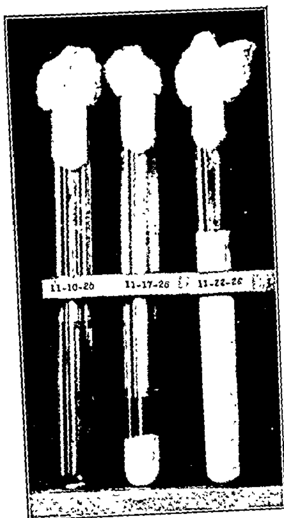


Fig. 4. Changes in the exudate in a case of streptococcal empyema. The tube on the left shows a seropurulent exudate. In the middle tube will be seen one from the same patient obtained seven days after that in the first tube and the tube on the right shows exudate obtained 12 days after that in the first tube. The seropurulent exudate has become transformed into one that is frankly purulent. Open drainage of the first exudate would be very dangerous; of the second, less dangerous; of the third, practically without danger. (From Graham, Singer and Ballon. Surgical Diseases of the Chest, Lea & Febiger.)

effects or by some method of continuous closed drainage. The simplest procedure to accomplish the latter is the insertion of a catheter through a cannula passed through the chest wall. After the cannula is withdrawn, the catheter, if it is of the same size, will fit snugly into the opening. The end of the catheter can be placed under water to prevent a free communication between the outside air and the pleural cavity, or gentle suction can be arranged so that the exudate will be constantly aspirated through the tightly fitting catheter.

If the aspiration of the pleural cavity reveals definite frank pus, an open drainage can be performed immediately, either by an intercostal incision or by the removal of a segment of rib one or two inches long. If the patient is a baby it is desirable not to make the opening too large. If an intercostal drainage is made it must be expected that in a large number of cases a subsequent rib resection will be necessary.

The important contributions of Tillett and his associates in the field of bacterial enzymes may greatly alter the management of pleural sepsis. These investigators have developed proteolytic enzymes of bacterial origin (streptokinase and streptodornase) which, in many instances, appear to effectively dissolve fibrin in the pleural space with break down of loculations permitting re-expansion of the lung. While most thoracic surgeons still feel that open drainage after the formation of thick pus is the surest, quickest, and safest way to cure an established empyema thoracis, there is no denying that many cases will respond well to a combination of antibiotic therapy with enzymatic débridement and repeated pleural aspirations.

Drainage should be maintained until the cavity is obliterated. The tube should not be removed until actual measurements have shown that the capacity of the cavity is approximately only 10 ml. An empyema should never be considered to be healed until there is positive evidence that the cavity itself is obliterated. In most cases of acute empyema, complete healing should occur in a period of from five to six weeks after the exudate has become definitely purulent. In many cases, healing will occur more promptly. In fact, in cases of pneumococcal empyema healing often occurs after one or two aspirations. One may expect that such an event will occur in from 10 to 25 per cent of cases of pneumococcal empyema. This tendency is more evident in children than in adults.

Chronic Empyema. It has already been said that one of the primary objects in the treatment of acute empyema is to prevent chronicity. Chronic empyema is less common in children than in adults. One of the most frequent causes of the condition is the failure

to provide adequate free drainage. The use, therefore, of methods of continuous closed drainage through small catheters should not be carried on too long in the treatment of an acute empyema because of the danger of permitting the condition to pass into a chronic state. It is important, therefore, that the drainage of an acute empyema should be at the most dependent portion of the cavity and that any tube used for the purpose should be of sufficient caliber to permit an easy exit of the pus.

Other important causes of chronic empyema are the presence of foreign bodies, communications with the lung or bronchial fistulas, cavities that cannot be obliterated spontaneously because of too much fibrosis of the lung and too much rigidity of the mediastinum, tuberculosis, or similar infections. Draining sinuses which persist after an empyema are not necessarily due to the presence of a chronic empyema. Such sinuses, for example, may lead to bronchial fistulas which are immediately beneath the chest wall but which have not closed spontaneously. Again the sinus may lead only to a necrotic portion of rib.

In establishing a diagnosis of chronic empyema it is desirable to determine not only the presence of a chronic empyema cavity but also to gain some idea of its size, location, and the possible cause of it. By the injection of a sufficient quantity of lipiodol through the external sinus, if one is present, some idea may be gained about the location and size of the cavity. If the case is one in which there is no external communication, aspiration with the introduction of from 50 to 100 ml. of air will usually enable one to outline the cavity in a fairly suitable manner. The diagnosis of tuberculosis or other granulomatous infections can usually be made by the excision of a piece of pleura for microscopic examination.

TREATMENT. Since, in the majority of cases of chronic empyema, the cause has been inadequate drainage, the treatment of a chronic case usually will be begun by the procedure of instituting adequate and satisfactory drainage in the most dependent portion of the cavity. This will often require the resection of segments of one or two ribs. In many cases even when the empyema cavity is of two or three years' duration, it may become obliterated within two or three months after the creation of satisfactory drainage. In nearly all cases, the cavity will at least become greatly reduced in size even if it is not completely obliterated (Fig. 5).

If, after the lapse of two or three weeks of adequate drainage, the cavity shows no signs of becoming obliterated, then some form of radical procedure must be considered. In such cases, the failure of the cavity to become healed is due to the fact that the overlying chest wall is too rigid to be pulled downwards to the lung and that the lung is too rigid to be pulled to the chest wall by the contraction of the scar tissue. The obliteration of an empyema cavity always occurs by progressive formation and contraction of scar tissue from the periphery toward the center of the cavity. All of the radical surgical procedures used for the treatment of chronic empyema are based on a principle of freeing the rigid walls of the cavity to permit them to come together and unite by the formation of scar tissue. If the empyema is relatively early, experience gained during World War II showed that decortication is very successful, just as in cases of clotted hemothorax. If the empyema is of long standing and the walls are comprised of scar tissue several centimeters thick, then the ribs, intercostal bundles, and outer empyema wall must be removed (Schede operation). In such an operation it is essential that the procedure should be sufficiently radical. Nothing is to be gained by halfway measures. It is essential that no overhanging edges of the empyema cavity should be allowed to remain. The cavity must be converted into a saucer with sloping edges in order to have it become satisfactorily obliterated by being filled up with soft tissues of the chest wall.

Spontaneous Nontuberculous Pneumothorax. Formerly it was a common belief that spontaneous pneumothorax was necessarily an indication of pulmonary tuberculosis. Now, however, it is well known that this condition often occurs in individuals who have no active tuberculosis. In such instances, it is usually due to the rupture of an emphysematous bleb beneath the visceral pleura or to the rupture of a cyst in a case of congenital cystic disease of the lungs. The treatment of such cases depends upon the degree of col-



Fig. 5. Chronic loculated empyema resembling lung abscess. This 66-year-old man had a febrile episode followed by chest pain and productive cough. Thoracentesis revealed thick pus. He was treated by rib resection and open drainage. The cavity closed over the next two months without further surgical treatment, and the patient remained well.

lapse. If the pneumothorax is less than 10 per cent, the air may be aspirated with a needle and the patient observed closely for recollapse. If the pneumothorax is greater than this, or if the patient is dyspneic, trocar thoracotomy with insertion of an intercostal tube should be done. When the tube is connected to a closed drainage apparatus, rapid re-expansion of the lung will occur. Patients with two or more episodes of collapse of the same lung should have an operation with resection of the offending blebs, and powdering (poudrage) of the pleural surfaces with an irritant to obliterate the pleural space permanently (Fig. 6). Patients with bilateral episodes of pneumothorax should have op-

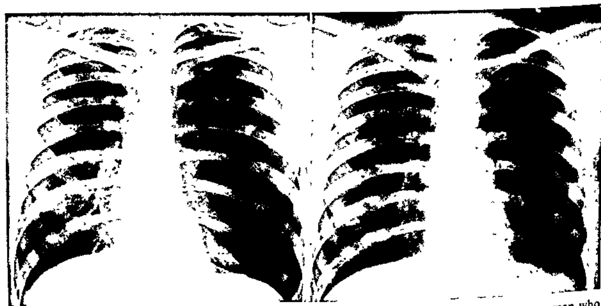


Fig. 6. Recurrent spontaneous pneumothorax due to apical blebs. The patient was a young man who had had a previous pneumothorax on the left side treated by closed catheter drainage. Left, shows the degree of collapse of the left lung on the second admission. The blebs can be seen at the apex. He was treated by thoracotomy, resection of the apical bullae, and poudrage. Right, shows the postoperative result.



Fig. 7. Solitary fibrous mesothelioma of the pleura. This 47-year-old man complained only of increasing shortness of breath. Left, shows the tumor before resection. Right, is the postoperative result. The tumor, which weighed 3500 grams, was completely removed.

eration on the recently affected side to prevent the future possibility of a fatal simultaneous bilateral collapse. Infections other than tuberculosis, such as pulmonary abscess, are sometimes associated with a spontaneous pneumothorax because of a rupture of the lesion into the pleural space. A complicating empyema almost invariably occurs in the latter case. As mentioned previously, staphylococcal pneumonitis with effusion in children is attended in a very high percentage of cases by tension pneumothorax, and for this reason closed tube drainage of the chest is mandatory during the effusion stage.

Tumors of the Pleura. Primary tumors of the pleura, both benign and malignant, are relatively rare. The commonest benign tumor is the fibrous mesothelioma (5). This is a circumscribed slowly-growing tumor which may reach large size before being discovered (Fig. 7). It is associated in a high percentage of cases with severe arthralgia Total surgical removal and cure is usually possible. Other rare benign tumors include lipoma, fibroma, and angioma.

The vast majority of malignant tumors involving the pleura are metastatic. Carcinoma of the lung frequently involves the pleura by direct extension, and breast cancers often metastasize to the pleura by way of the internal mammary lymph chain. A true primary malignant tumor is the papillary mesothelioma. The normal mesothelial cells undergo malignant change and spread along the surface in a series of papillary projections. Pleural effusion is always present and is usually excessive in amount. The prognosis is very poor.

There are other conditions which sometimes simulate tumors of the pleura. Occasionally in pneumothorax cavities, fibrin bodies are formed which are roughly spherical in outline and often appear in x-ray films like tumors. Areas of calcification in the pleura may sometimes be mistaken for a new growth. Again, various kinds of cysts of the pleura have been described, of which some are echinococcal in origin but others are due to congenital defects.

The problem of diagnosis of pleural tumors and the differentiation from benign processes is at times difficult. Sooner or later a pleural effusion almost always develops, which may or may not be bloody. The presence of blood does not necessarily mean that a malignant process is present. There are a large number of inflammatory conditions which give rise to pleural effusion and which must be considered when a diagnosis of pleural tumor is entertained. Smears and cultures of the aspirated fluid will help to rule out a tuberculous or pyogenic infection. The fluid should be examined for cells by exfoliative cytology technics or by centrifuging the fluid

and making paraffin blocks of the sediment. In almost all cases where a malignancy is present, identifiable tumor cells will be found. In fact, if such studies are negative on several occasions, then the diagnosis of tumor should be seriously questioned. The problem of an undiagnosed pleural effusion is difficult. Needle biopsy of the pleura has been used, but the tissue obtained is small. It is probably best in such cases to proceed directly with exploratory thoracotomy. In this way, ample tissue for diagnosis can be obtained and decortication can be done if the lung is trapped under a limiting membrane.

With advanced malignancies of the pleura, rapid reaccumulation of fluid frequently poses a therapeutic problem because of dyspnea. This is especially true with papillary mesotheliomas and metastatic breast cancers. The production of fluid can usually be controlled by the intrapleural use of radioactive gold or nitrogen mustard. An occasional patient will require surgical removal of the involved pleura to obliterate the pleural space.

THE MEDIASTINUM

The mediastinum is very important surgically because within that space are located the heart, the giant vessels, the trachea and its bifurcation, the esophagus, and important nerve trunks. For practical purposes it is well to bear in mind the four anatomic divisions of the spaces—superior, anterior, middle, and posterior, according to the relations which they present to the pericardium.

Mediastinal Emphysema. It is important to realize that the persistence of a pressure less than that of the atmosphere is necessary for the proper functioning of many of the mediastinal structures. Serious elevations of pressure in the mediastinum therefore may result in physiologic disturbances which may be sufficiently extreme to cause death. One source of such an increased mediastinal pressure is the gradual accumulation of air within it, a condition known as mediastinal emphysema. This condition is caused by a rupture of subpleural alveoli and dissection of air back along the bronchovascular structures to the hilum of the lung, and from there to the subcutaneous tissues of the suprasternal notch. Here the condition may be recognized early by swelling and crepitation. Conditions in which mediastinal emphysema is seen as a complication include asthma, influenza, pertussis, and pneumonitis. It sometimes occurs following indirect trauma to the chest.

The diagnosis is not difficult if the condition is kept in mind. The patient may complain of severe substernal pain simulating heart disease. Subcutaneous air first makes its appearance in the neck, but may spread to involve large areas of the body. Auscultation of the chest will reveal a crunching sound synchronous with the heart beat, caused by compression of the mediastinal air by motion of the heart (Hamman's sign). The blood pressure may be normal or low, depending upon the degree of mediastinal tension and circulatory obstruction.

Emergency treatment is necessary if there is severe circulatory compromise. Decompression is done by making a collar incision in the neck and opening the fascial planes leading into the superior mediastinum. In addition, tracheostomy is sometimes advisable.

Mediastinitis. Many of the acute infections of the mediastinum represent the spread of infection from the mediastinal lymph nodes. Probably most of the acute infections of the mediastinum occur as injuries to the esophagus. These result from the perforation of the esophagus by sharp foreign bodies which have been swallowed and also from perforations in association with benign stricture or carcinoma of the esophagus. The antibiotics, particularly penicillin, have proved remarkably effective in the control of mediastinal infection. The development of diffuse mediastinal phlegmon is now a rare occurrence, and abscesses which require drainage are far less frequent than formerly. Perforations occurring as a result of instrumentation, if small, may often not require operation of any sort provided the endoscopic examination was done for non-neoplastic disease and if antibiotic is given promptly and in adequate dosage. Perforations occurring in cases of carcinoma of the esophagus are best handled by doing an immediate resection and esophagogastric anastomosis. Large perforations in nonmalignant esophageal disease should be closed immediately with either two layer suture of the perforation or resection and anastomosis as dictated by the pathology. An

abscess of the mediastinum may often be recognized on x-ray examination by an undue prominence of the mediastinal shadow, particularly in the upper part. Since most of the mediastinal abscesses occur in the superior mediastinum, the majority of them can be reached successfully for drainage through an incision in the neck. The location of such an incision will depend considerably upon the location of the abscess, especially whether it is in the anterior or posterior part of the mediastinum. Sometimes the usual collar incision for thyroidectomy will be adequate. In other cases, especially those due to a perforation of the esophagus, an approach along the anterior border of the sternocleidomastoid is preferable.

Chronic infections of the mediastinum are often tuberculous and they frequently originate from tuberculosis of the spine. They are, therefore, often in the posterior mediastinum. If secondarily infected, they demand drainage usually through a posterior mediastinotomy incision. If they are not secondarily infected, they should be aspirated and treated like tuberculous abscesses elsewhere. The possible connection with tuberculosis of the spine should always be borne in mind so that appropriate treatment will be given to that condition also.

Mediastinal Tumors. With the development of thoracic surgery, mediastinal tumors have become of increasing importance because of the possibility of extirpating many of them successfully. The most common effect of a mediastinal tumor, regardless of its type, is pressure on one or more important structures. In malignant tumors there may be, in addition to pressure effects, actual involvement of organs by extension or metastasis.

The most common result of increased mediastinal pressure caused by a tumor is dyspnea which is due probably not so much to compression of the air passages as to compression of the large veins. The vein which is particularly affected is the superior vena cava. Signs of obstruction of this large vein are usually present at some time in the case of any large mediastinal tumor. The specific signs of compression of the superior vena cava are cyanosis, orthopnea, dilatation of the superficial veins of the thorax and later, pulmonary edema, pleural and pericardial effusion. Determinations of the venous pressure in such cases show an increase. Subcutaneous edema of the head, neck, and upper part of the thorax occur in the more severe cases of superior caval obstruction, likewise headache, vertigo, deafness, epistaxis, tinnitus, and even loss of consciousness with epileptic convulsions may occur. The resulting effect depends somewhat upon whether the obstruction has occurred above or below the orifice of the azygos vein. If the obstruction is above the azygos orifice the symptoms are less severe than if it is below that point. The symptoms just mentioned may occur with any mediastinal tumor of sufficient size. In malignant tumors there will also be present signs and symptoms resulting from the development of metastases in other organs.

Mediastinal tumors, like many of the tumors in the chest, can only be diagnosed by surgical exploration and pathologic examination. Experience has shown, however, that, statistically speaking, most mediastinal neoplasms are characteristically found in a certain mediastinal compartment, although certainly some overlap occurs. For this reason, they are most conveniently discussed with respect to location.

Superior Mediastinum. The most common tumor of this region is a substernal extension of an adenomatous goiter of the thyroid gland. They are usually connected to the cervical thyroid, and their blood supply is that of the normal gland. They are therefore best removed through a transverse cervical incision. Because of excessive size, about 5 per cent of these tumors will require an additional median sternotomy to facilitate removal. Rarely, aberrant parathyroid tumors and bronchogenic cysts will occur in the superior compartment.

Anterior Mediastinum. The principal tumors here are thymomas and teratoid tumors. Both exist as benign and malignant forms. Thymomas are a poorly understood group of neoplasms, and histologically there may be great difficulty in classifying the tumor and estimating the degree of malignancy. Also, an unexplained relationship exists between benign thymomas and myasthenia gravis, in that some patients with the disease are improved by removal of the gland. Teratoid

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pends upon the degree of malignancy. Occasionally, a dumbbell or hourglass tumor will be encountered where the intraspinal component causes spinal cord compression.

SURGICAL CONDITIONS OF THE DIAPHRAGM

The chief function of the diaphragm is to assist in the creation of a negative intrathoracic pressure by the enlargement of the thorax, which is produced when it descends on inspiration. The diaphragm is also important because it separates the abdominal from the thoracic cavity. It is present only in mammals. A congenital absence of the left half has been reported on several occasions, a condition which does not seem to be incompatible with health and long life. Spasms of the diaphragm are responsible for the condition known as *hiccup* or *singultus*.

Eventration of the Diaphragm. Normally, the right leaf of the diaphragm lies about 1 cm. higher than the left. In some individuals, however, one leaf, usually the left, is abnormally high. This constitutes the condition known as *eventration of the diaphragm*. Into the saclike formation which results, one or more of the abdominal organs are likely to be displaced, especially the stomach, colon, or spleen. The usual causes of such a condition, when not produced by operations on the phrenic nerve, are congenital atrophy, neuromuscular degeneration following injury, neuritis or other involvement of the phrenic nerve, certain infectious diseases and changes in the musculature of the diaphragm in association with pseudohypertrophic lipomatosis and myositis. This condition is not incompatible with good health. Its chief importance lies in the possibility of confusing it with a true diaphragmatic hernia. It is recognized by the high position of the diaphragm and by the fact that the abdominal viscera are seen to be below it rather than above it. A small pneumothorax created for diagnostic purposes will often settle the diagnosis definitely between an eventration and a hernia of the diaphragm. Ordinarily the condition demands no surgical treatment.

Diaphragmatic Hernias. These may be divided into the nontraumatic and traumatic. The nontraumatic hernias are essentially congenital and are due to the passage of an abdominal organ through a congenital opening in the diaphragm. The traumatic varieties may occur not only from penetrating injuries but also from a tearing of the diaphragm away from its attachments to the thoracic wall. Such hernias, for example, may occur after a severe automobile injury in which there has been no penetration of either the thorax or the abdomen (Fig. 9). Another classification is that which comprises congenital, acquired, and traumatic hernias (see also Ch. 34).

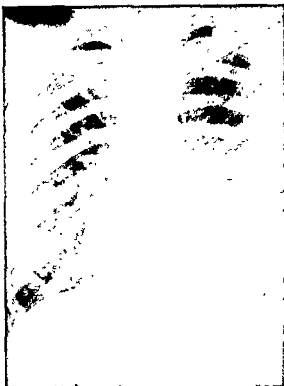


Fig. 9. Traumatic hernia. This 32-year-old man was in an automobile accident six months prior to examination. His complaints were dyspnea and dysphagia. At operation there was a large tear in the diaphragm, with herniation of most of the stomach into the left thoracic cavity. There was complete recovery following surgical repair.

The most common symptoms of diaphragmatic hernia are abdominal pain, vomiting relieved by a change in position, symptoms of intestinal obstruction, dyspnea, dysphagia, hemoptysis, cyanosis, and pain in the left shoulder. Frequently abnormal tympany is found over the lower part of the thorax. Displacement of the heart to one side is also frequently noted. X-ray examination with a barium meal almost always reveals the true

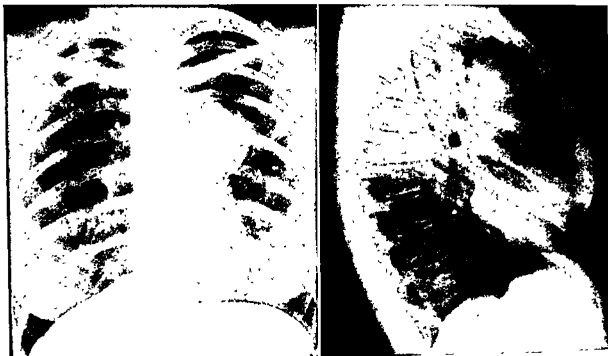


Fig. 8. Mediastinal tumor (teratoid). This 26-year-old woman had no symptoms. The lesion was discovered on a survey x-ray film. Pathological examination revealed hair, skin, bronchial epithelium, and pancreas. There was no evidence of malignancy.

tumors are among the more common types of mediastinal tumors. The benign dermoid cyst contains epithelial elements, such as skin, hair, and teeth, while true benign teratomas will contain elements of all three germ layers in varying combinations. Any of these elements may undergo malignant degeneration, with subsequent invasion of the capsule and surrounding structures.

Both thymic and teratoid tumors will usually present to one side or the other, so that removal can be done through a thoracotomy without having to cross the sternum. The benign forms are encapsulated and are easily removed with complete cure (Fig. 8). With the malignant forms, total removal is usually not possible and the prognosis is very poor.

MIDDLE MEDIASTINUM. Tumors of the lymphoma group (lymphosarcoma, Hodgkin's disease, and so forth) are the most common mediastinal tumors encountered, but are usually not amenable to surgical extirpation and are treated by some form of nonoperative therapy. Cysts of bronchogenic and pericardial origin are found in this area. Bronchogenic cysts are closely related to the trachea or main stem bronchi and may cause pressure on the air passages. Occasionally, rupture into a bronchus occurs with discharge of the cyst contents. Pericardial cysts are characteristically found in the pericardiophrenic angle. They are filled with a clear fluid and almost never cause symptoms. Both types of cysts should be removed if their presence is known, because operation is necessary for an exact diagnosis.

POSTERIOR MEDIASTIUM. Tumors in this area are related either to the esophagus or to nerve structures. Esophageal and gastroenteric cysts are usually in close association with the esophagus, and thus may cause dysphagia. They can usually be completely removed without having to resect the esophagus. Neurogenous tumors are either somatic in origin, arising from the intercostal nerves, or autonomic, arising from the sympathetic chain (6). There are a number of different histologic cell types in each group, with several gradations of malignancy. The most common benign tumor is the neurilemmoma, derived from the intercostal nerve sheath. The most malignant type is the neuroblastoma (sympathicoblastoma), which arises from primitive autonomic nervous tissue and is seen almost exclusively in infancy. Ease of removal of a posterior neurogenic tumor de-

pends upon the degree of malignancy. Occasionally, a dumbbell or hourglass tumor will be encountered where the intraspinal component causes spinal cord compression.

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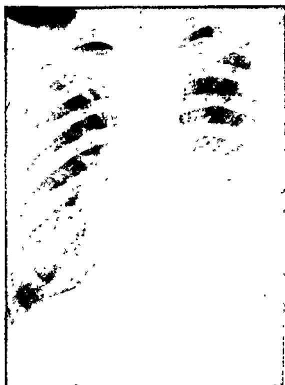


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condition. The great danger of diaphragmatic hernia is that of strangulation. It is probably desirable, therefore, to operate on all cases, even if only mild symptoms are present, lest severe or even catastrophic manifestations, such as massive hemorrhage, take place (7).

Operative repair of this condition can often be performed through either an abdominal or a thoracic incision. In many cases, it is helpful to make the approach through both incisions. It may be difficult to separate adherent intestine and to make a satisfactory reduction without the combination of both incisions. In any case, the operation will be made much easier if the diaphragm previously has been paralyzed on the affected side by crushing the phrenic nerve in the neck. Previous operation on the phrenic nerve ordinarily should be performed two or three days before the operation for the repair of the hernia. In some cases the repair is easy but in many it is exceedingly difficult. Especially is that true in those cases in which the diaphragm has *been torn away from the anterior chest wall.* In nearly all cases it will be found helpful to use sutures of living fascia obtained from the patient's own fascia lata. Ordinarily the lung rapidly expands to fill up the space formerly occupied by the herniated viscus.

Wounds of the Diaphragm. Whenever recognized, penetrating wounds of the diaphragm should be promptly closed because of the possibility of the subsequent development of *a diaphragmatic hernia.*

Tumors of the Diaphragm. Primary neoplasms of the diaphragm are very rare. In a careful review of the literature for the past 50 years Binney (1931) could find but four instances of primary tumor of the diaphragm. One of these was reported as multiple fibromyoma, another as fibromyosarcoma, another as sarcoma, and the fourth as lipoma.

DISEASES OF THE TRACHEA

Surgical diseases of the trachea are uncommon. Foreign bodies lodged in the trachea should be removed bronchoscopically. *Fistulas* that occur between the trachea and esophagus are either congenital or acquired. The congenital variety is usually associated with an atresia of the esophagus, making it possible to detect the malformation soon after birth. The treatment is surgical, with one-stage closure of the fistula and restoration of esophageal continuity. Acquired tracheo-esophageal fistulas are most commonly seen as a complication of advanced carcinoma of the upper esophagus, where surgical closure is rarely possible. Tumors of the trachea are very rare. The benign tumors which have been described include papillomas, fibromas, lipomas, intratracheal thyroid tissue, lymphomas, chondromas, and chondroosteomas. The benign tumors usually occur in the upper third of the trachea or in the region of the bifurcation. They can usually be best treated through the bronchoscope.

Of the malignant tumors of the trachea, carcinoma is the most common, but the actual number found in this location is still very small. They usually arise in the lower third and are almost always of the squamous variety. Cough, hemoptysis, and wheezing are the predominant symptoms. Metastases usually occur late. Early perforation is to be ex*pected from those malignant* tumors which arise in the posterior wall. The *treatment* of these tumors is generally unsatisfactory by any method. Removal of the involved portions of the tracheal wall and the application of a dermal graft to the defect gives the best chance of cure. Palliative measures include bronchoscopic removal of all gross tumor and radon seed implantation, or the use of high voltage roentgen therapy to the area. *Nitrogen mustard given intravenously* may be helpful in the control of symptoms by reducing the tumor and relieving obstruction.

DISEASES OF THE BRONCHI

In considering surgical conditions of the bronchi, it is essential to understand some of the specific effects of conditions which obstruct or cause inflammation of a part of the bronchial tree. Because of the relatively straight direction of the bronchus of the right lower lobe, foreign bodies which are aspirated are more likely to fall into that bronchus than into any other part of the bronchial tree. An obstructive lesion that is complete is almost always followed by an absorption of *air in* that portion of the lung to which the particular bronchus leads, with the result that the condition of atelectasis occurs. In the dog

there is collateral circulation of air in different lobules, and occasionally even between different lobes of the lung. It would seem also that some evidence exists that in man similar collateral circulation of air occurs. In spite of this interesting fundamental physiologic fact, clinically in the human being, atelectasis of a lobe almost always occurs as a result of complete obstruction of the bronchus of that lobe.

Inflammation of the bronchi of a suppurative character often produces purulent inflammations of the lung, especially if there is a more or less complete obstruction of the bronchus by a foreign body or by some other agent. Obstructive lesions are not always foreign bodies, they may be new growths or they may be scars resulting from severe inflammation of the bronchus. When destructive inflammation of the wall of a large bronchus occurs, the cartilage in the wall is more or less destroyed and the condition of bronchiectasis results. Only the large bronchi have cartilaginous walls.

It is important to emphasize the fact that the normal drainage from the lung is through the tracheobronchial tree. This is brought about chiefly by two mechanisms, of which one is the expulsive action of the cilia of the epithelium lining the mucous membrane, and the other is the act of coughing. Likewise, it should be recalled that under normal conditions the bronchi are constantly changing their size and direction with each act of respiration, i.e., on inspiration, the bronchi enlarge and become lengthened. This lengthening tends to make many of them in the lower lobes more perpendicular and corresponding changes occur in the direction of the bronchi in other parts of the lung. The movements just mentioned are dependent upon the action of the peribronchial muscle. It becomes apparent, therefore, that an inflammatory process or any other factor which alters the normal action of the bronchial muscle is likely to have some effect not only on the act of respiration itself but also probably on the normal mechanisms for the expulsion of secretions from the bronchial tree. Again, consideration should be given to the fact that although coughing is one of the important mechanisms for the expulsion of products of inflammation of the bronchial tree, too violent coughing may be harmful because each act is necessarily preceded by a deep inspiration which may spread the products of inflammation into previously uninvolved alveoli of the lung. There is at the present time an insufficient amount of knowledge concerning the various points just discussed to permit one to be dogmatic. Much diagnostic information can be obtained by bronchography (Fig. 10, 11).

Foreign bodies. Aspiration of foreign bodies into the bronchus may occur at any age but is most frequently seen in young children. The majority of foreign bodies are objects which should never have been put into the mouth, although certain foods, such as peanuts, are frequent offenders. More foreign bodies pass into the right bronchus than into the left because of the anatomic arrangement of the bronchi. The symptoms and signs produced by a foreign body depend upon the size and shape of the object, its ultimate location in the bronchus, and whether partial or complete obstruction of the bronchus is present. All foreign bodies will cause cough at the time of aspiration, but this may happen without the realization that a solid object went down. Wheezing, particularly during expiration, is a valuable clue. If the foreign body is opaque, it can be accurately localized on the chest films. If it is nonopaque, indirect evidence of its presence can be detected on inspiratory and expiratory chest films which may demonstrate obstructive emphysema of the lung behind a partially blocked bronchus. Complete block of the bronchus will invariably lead to distal atelectasis. The treatment of foreign bodies in the bronchi is bronchoscopic removal as soon as the diagnosis is made. This should be done by an expert trained in foreign body removal. In this way, 98 per cent of foreign bodies can be extracted. Occasionally, a thoracotomy and direct opening of the bronchus will be necessary. Retention of an undetected foreign body may lead to hemoptysis, lung abscess, or bronchiectasis at a later time. Peanuts are particularly likely to result in gangrenous changes in the lung because of the irritating fatty acids which are formed during decomposition. Once stenosis of the bronchus or irreversible septic changes in the lung have oc-

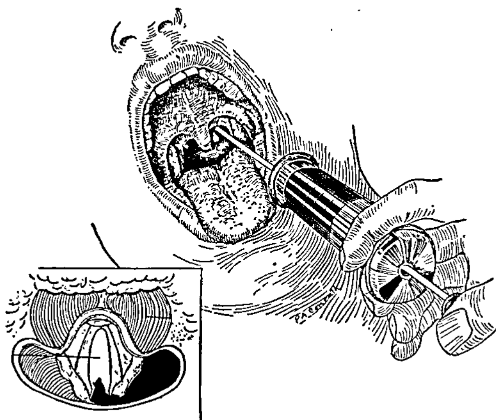


Fig. 10. The aspiration method of injecting lipiodol (J. J. Singer). The method of introducing the iodized oil into the posterior pharynx while the patient breathes deeply; the inset shows how the oil collects in the interarytenoid fossae. It then trickles between the vocal cords and is aspirated into the bronchial tree. In little children the method can seldom be used; for them bronchoscopic injection of the lipiodol is preferable. (From Graham, Singer and Ballon. Surgical Diseases of the Chest, Lea & Febiger.)



Fig. 11. Normal bronchial tree as outlined by

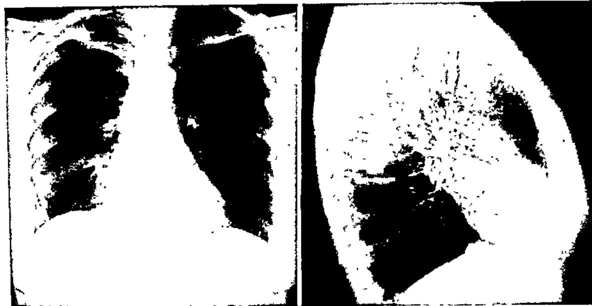


Fig. 12. Right middle lobe atelectasis. This patient, a 62-year-old woman, had a chronic cough for 12 years. At operation the right middle lobe bronchus was compressed by a ring of enlarged, chronically infected lymph nodes. Note the complete atelectasis of the lobe on the lateral x-ray projection.

curred, resection of the lobe or segment involved will be required to effect a cure.

Bronchostenosis. In the opening paragraph of this section some of the mechanical factors involved in bronchostenosis have already been discussed. The symptoms and physical signs differ according to the location of the stenosis. The amount of dyspnea is naturally dependent to a great degree upon the amount of lung involved. As might be expected, therefore, a stenosis of the trachea or of both bronchi at the bifurcation results in more dyspnea than if the lesion involves the bronchus of only one lobe. Some degree of cough is usually but not always present. Inspiration is prolonged, difficult, and wheezing. Expiration, as a rule, is much less difficult. Stridor is loud in stenosis of the trachea and of the bifurcation but it is usually absent in lesions lower down.

The physical signs of an obstruction of a bronchus are essentially those of atelectasis (Fig. 12). Again those features vary depending upon the amount of lung involved. If a main bronchus is completely obstructed, the whole lung may show evidence of massive atelectasis. The patient complains of pain on the affected side, the intercostal spaces on that side are narrowed, there is more or less limitation of respiratory movement, and the heart and mediastinal contents are found to be drawn over toward the affected side. The diaphragm on that side is elevated, the breath sounds are usually absent or diminished, and the percussion note is correspondingly dull.

The ordinary x-ray examination reveals an opacity in the region of the atelectasis, a deflection of the mediastinal contents toward the affected side and usually also a compensatory emphysema of the other lung. Bronchoscopy should be done to determine whether the stenosis is due to a foreign body, an inflammatory stricture, or a tumor, or to ascertain whether the obstruction is due to pressure on the bronchus from the outside caused by perhaps a tumor of the mediastinum. If the tumor is found within the bronchus itself, a biopsy made at the time will reveal its character. At times, bronchograms are helpful in outlining a stenotic area that is outside bronchoscopic vision.

The treatment of bronchial stenosis will, of course, depend considerably upon the nature of the stenosis. If it is due to a foreign body, the latter should be removed through a bronchoscope. Likewise, benign tumors can often be removed in that way. If, however, it is due to a carcinoma of the bronchus, the treatment should be of a different sort which will be found discussed under Tumors of the

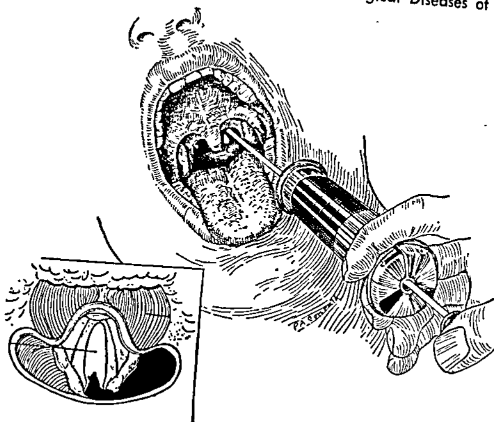


Fig. 10. The aspiration method of injecting lipiodol (J. J. Singer). The method of introducing the iodized oil into the posterior pharynx while the patient breathes deeply; the inset shows how the oil collects in the interarytenoid fossae. It then trickles between the vocal cords and is aspirated into the bronchial tree. In little children the method can seldom be used; for them bronchoscopic injection of the lipiodol is preferable. (From Graham, Singer and Ballon. Surgical Diseases of the Chest, Lea & Febiger.)



Fig. 11. Normal bronchial tree as outlined by

chial fistula is that hemorrhage, which may be severe, occurs from its opening occasionally. In most cases, however, the chief complaint of the patient is the inconvenience caused by wearing a dressing and the impossibility of immersing the fistula under water because of the danger of drowning by the direct entrance of water into the lungs through the external opening.

There is a tendency for all bronchial fistulas to become healed spontaneously. When successful, this occurs as a result of the circular contraction of the peribronchial tissue and of scar tissue around the opening of the fistula. If a large bronchial fistula becomes adherent to the skin it is less likely to become closed than if it is situated deeply. It is well not to hurry too much in the ordinary closure of bronchial fistulas because the great majority of them will close spontaneously if an opportunity for them to do so is given over a period of several months. If, however, a decision has been made to close a fistula by surgical methods, the operation should be preceded by an attempt to make an exact diagnosis of the condition of the fistula. One should attempt to find out particularly its size, its extent, and whether or not a foreign body is present within. All of this information can usually be obtained by injecting the sinus with lipiodol. Surgical closure of the fistula is based on the application of a variety of principles. In some cases, repeated cauterizations of the opening of the fistula are sufficient but usually not in the chronic cases in our experience. Another principle is to mobilize the lung from its attachments to the chest wall and to close the fistula with several rows of sutures after the mobilization has been effected. Such a procedure usually will permit the circular contraction of scar tissue, which is helpful in the closure. Another principle which is very effective is the transplantation of a vascular flap of muscle into the opening of the fistula. This latter procedure is especially helpful in cases in which the bronchial fistula leads into a pulmonary cavity of considerable size. In some cases, a partial resection of the lung will be necessary. The incidence of bronchial fistula, both as disease, such as lung abscess, and following surgical operations on the lung, has been greatly reduced since the introduction of antibiotics.

Bronchiectasis. Bronchiectasis is a chronic disease state characterized by dilatation of the bronchi and infection of the bronchial walls and surrounding peribronchial tissues. It may appear as a primary disease, or may develop secondarily distal to a chronic bronchial block, such as caused by a retained foreign body or stricture. The cause of primary bronchiectasis is not known. There is little evidence to support a congenital origin for the bronchial dilatations, although bronchiectasis occurs in a high percentage of patients with situs inversus. These individuals also usually have severe sinus disease (Kartagener's triad) (8). Most pathological studies indicate that primary bronchiectasis, like the secondary type, is probably the result of infection of the bronchial wall and surrounding lung. This infection causes a persistent lymphadenopathy and chronic bronchial compression which leads to distal pneumonitis and eventually to dilatation of the bronchi. These bronchi drain poorly and accumulate purulent secretions which, in turn, extend the infectious process, and a vicious cycle is set in motion. This theory is supported by good evidence. In almost all cases there is a preceding history of pulmonary infection. Frequently the disease develops after a severe bout of childhood pertussis or bacterial or virus pneumonitis. There is a definite relationship between sinus disease and bronchiectasis, and the distribution of the bronchial involvement principally to the lower lobes suggests that purulent secretions from the upper respiratory tract can "seed" the infection into the bronchi in the area of drainage.

The pathological changes seen in the lungs of patients suffering from bronchiectasis vary greatly, depending primarily on the amount of infection present. The bronchial dilatations are generally confined to the medium sized segmental bronchi and may be saccular (Fig. 13) or tubular in configuration, although most cases contain elements of both types. Purulent material, often foul, is retained in these pockets. The bronchial wall is thickened and irregular, and miscroscopic examination will show a chronic inflammatory response and even focal abscess formation. Each involved bronchus is surrounded by an area of chronically infected lung. A varying

Lung. If the stenosis is due to an inflammatory stricture, there will usually be an associated bronchiectasis which will require the sort of treatment discussed under that heading. If, on the other hand, it is due to the pressure of a mediastinal tumor upon the wall of the bronchus, appropriate treatment for the mediastinal tumor should be undertaken.

Bronchial Tumors. Most tumors arising in the bronchi are carcinomas, discussed under Tumors of the Lung. Benign tumors also occur in the bronchi, mostly polyps or adenomas, arising from the bronchial epithelium. There is much confusion about which should be regarded as benign, for many so-called benign adenomas are potentially malignant. Tumors of this type have rarely been completely removed through the bronchoscope by electrocoagulation and in other ways, and opinion is increasing that such limited removal is unsatisfactory. A lobectomy or a total pneumonectomy will give more assurance against a recurrence in cases in which malignant changes have occurred. A differentiation between a benign and a malignant tumor of the bronchus is not easy to make from a bronchoscopic biopsy.

Broncholithiasis (Lung Stones). This condition is by no means as infrequent as a survey of the literature would indicate. We have noted their appearance in approximately 2 per cent of our cases of chronic pulmonary suppuration. The expectorated stones usually have about the same relative proportion of calcium phosphate and calcium carbonate that is contained in bone. They are usually multiple, although occasionally they may be single. In one of our own cases, the patient coughed up 126 stones during a period of six months. They vary in size from merely granular particles to stones which may weigh several grams. They are irregular in outline. They are often found in individuals with healed pulmonary tuberculosis but they may also be present wtih a variety of other conditions, such, for example, as all forms of pulmonary suppuration, tumors, cysts, actinomycosis, and even with silicosis. It is possible that, in many cases, broncholiths are concrements which have ulcerated through into a bronchus or into the lung from calcified tracheobronchial and bronchopulmonary lymph nodes.

Associated with the stones usually are frequent and severe attacks of coughing, sometimes with pain in the chest. Following the expulsion of the stone there may be blood in the sputum which occasionally is sufficient to be classed as a severe hemorrhage. The bleeding is probably due to the trauma of the mucous membrane produced by the sharp stone. Sometimes, if they are of sufficient size, the stones may be seen in an x-ray film, but usually they cannot be distinguished from calcified areas in the neighboring lymphatic nodes. Ordinarily, the condition demands no special treatment. It is to be emphasized, however, that sometimes, because of the element of hemoptysis, such patients are wrongly diagnosed as having active tuberculosis. Occasionally, bronchoscopic removal of broncholiths is indicated.

Bronchial Fistula. Any abnormal communication between the bronchial tree and another surface or organ is termed a bronchial fistula. The most common site for such a fistula is between some part of the bronchial tree and the pleural cavity. Often, however, fistulas are noted in patients who have recovered from an operation for empyema or a lung abscess with the bronchial opening communicating directly with the skin. They naturally vary greatly in size depending upon whether they lead directly from a large bronchus or from some one of the finer divisions of the bronchus. They may be either acute or chronic. For the most part, the small ones heal spontaneously in a relatively short period of time. It is only the larger ones which tend to remain chronic. Bronchial fistulas occur with any form of inflammation of the lung in which there is destruction of tissue. They are, therefore, especially likely to be found in cases of pulmonary suppuration of various kinds and also in pulmonary tuberculosis. The bronchial fistula may secrete mucus or mucopus or the product of the organ with which it communicates, e.g., bile in a bronchobiliary fistula. The character and the amount of the secretion from a bronchial fistula are considerably altered by the condition of the upper respiratory tract. When the patient develops a coryza or an acute infection of a nasal sinus, the mucous membrane of the fistula becomes congested and the secretion is greatly increased.

One of the most serious features of a bron-

ish sediment which consists of pus cells, fat rests, Dittrich plugs, and detritus. The expectoration of blood is frequent, sometimes it amounts to only a streaking of sputum but at other times it may be a severe hemorrhage. Fever, sweats, and chills are common complaints. These occur intermittently and between such attacks the patient may feel reasonably well. They are probably due to repeated attacks of inflammation of the pulmonary parenchyma adjacent to the bronchiectasis. It is not uncommon for a patient with bronchiectasis to be required to go to bed with a bout of fever for a week or ten days at a time, at irregular intervals, two or three times a year. The introduction of antibiotics has done much to control secondary infection and lessen the quantity and purulence of the sputum in these patients.

The physical findings in bronchiectasis are suggestive but not specific. Patients with well-established disease are usually thin and pale. Mouth breathing and adenoid facies suggest concomitant sinus disease. The breath is unpleasant, and the cough loose and rattling. Moist rales and bronchi can usually be heard over the lower lobe areas. In severe cases, clubbing of the nails is present, and there may even be cyanosis.

All patients suspected of having bronchiectasis must have bronchoscopy and bronchograms to confirm the diagnosis. Bronchoscopy is needed to determine the presence or absence of a foreign body or a stenosis and gives an indication of the areas of involvement by the distribution of the pus. Studies on the aspirated material also will help rule out tuberculosis as the primary disease. Bronchography is always necessary to confirm the diagnosis and to establish the anatomic limits of the disease, a highly important point when surgery is contemplated.

TREATMENT. The treatment of bronchiectasis is both medical and surgical. Medical measures of great value are postural drainage, antibiotics, and control of sinus disease. The removal of secretions that have collected in the bronchiectatic pockets of the lower lungs is greatly facilitated by placing the head down for a few minutes several times a day and allowing the secretions to flow down hill where they may easily be coughed out. Antibiotics are used to control the purulence of the sputum and prevent secondary infections. They may be given intramuscularly and by aerosol spray. Severe sinus infections should be treated vigorously to abolish the postnasal drainage into the lungs. Occasionally, patients will be relieved of symptoms by a change to a warm, dry climate.

Although conservative measures are helpful, most cases with well-defined alterations in the bronchi will require surgery for relief of symptoms. The risk of bronchiectasis surgery today is practically nil, and complete relief or marked improvement can be expected in 75 to 80 per cent of the cases. The patients should have accurate mapping of the lungs by bronchography and a period of medical preparation by the measures mentioned above to reduce sputum production to a minimum before operation. Patients with extensive involvement on both sides are not surgical candidates. The principal areas which may require removal are the lower lobes on both sides, the lingular segment of the left, and the middle lobe on the right. Occasional patients with limited bilateral disease can be helped by staged bilateral operations.

DISEASES OF THE LUNG

Congenital Abnormalities. Various abnormalities of the lung have been described. Occasionally, an entire lung is absent (Fig. 14). More frequently, a condition has been described in which one lung has maintained its fetal state and has never expanded (hypoplasia). Rarely, a portion or an entire lobe will develop as a mass of small cystic structures which may or may not retain some bronchial communications. The blood supply to these areas is usually anomalous and frequently is a systemic artery coming directly from the aorta. This condition has been termed pulmonary sequestration. A similar but more diffuse condition is congenital cystic disease of the lung. The cysts are usually small but may reach large size and may be distributed extensively throughout both lungs. There is a high association of this abnormality with cystic changes in the pancreas, kidney, and liver. Again, there may or may not be bronchial communications with the cysts, but when there are, infection frequently develops. Some cases diagnosed as lung abscess in children are, in reality, infected cysts. Surgery is

Fig. 13. Above, extensive cystic bronchiectasis of left lung. This 41-year-old woman had a chronic cough all her life. Sputum production was great. She was treated by left pneumonectomy. Below right, shows section of lung, with bronchi enlarged to form cystlike cavities.



degree of distal atelectasis is usually present (9).

The chief complaints of the patient are cough, expectoration, foul breath, hemoptysis, and fever. The amount of sputum is variable, but it may exceed 1,000 ml. per day. It often has an odor due to putrefaction which is rather characteristic and which makes the patient with the disease often abhorrent to those with whom he is in contact. Characteristically, the sputum, when collected in a glass vessel, is seen to separate into three layers, the upper of which is nearly colorless or slightly greenish and contains air bubbles, pus, and mucus. The second layer contains many of the products of the first layer but has less air. The third layer contains a green-



Fig. 15. Pulmonary abscess caused by Friedländer's bacillus. This 54-year-old man developed fever and cough. Left, shows presenting film. Klebsiella organisms were recovered from sputum, and treatment with streptomycin and tetracycline instituted. Right, taken one month later shows almost complete clearing. The patient had no further difficulty.

6. Miscellaneous factors of various kinds may also produce abscess of the lung, such as actinomycosis and blastomycosis.

Many different kinds of bacteria have been found in cases of pulmonary abscess. Besides the ordinary pyogenic bacteria, it is common to find various types of spirochetes and fusiform bacilli. Anaerobic bacteria are also common. *Klebsiella pneumoniae* (Friedländer's bacillus) can cause necrosis and cavitation of large areas of lung without causing very much surrounding inflammatory response (Fig. 15).

The most common site of pulmonary abscess is in the right lower lobe. If a lung containing a true abscess is cut open, a distinct pyogenic membrane will be seen. There will be numerous bronchial openings; fibrin and pus will be contained within the cavity, the lining of which is usually not smooth and is gray or brown in color. The term "gangrene" is applied to a condition in which a whole lobe or a whole lung is found to have undergone liquefaction necrosis without any sharp line of demarcation between normal and diseased tissue, and with a greenish black or brownish black appearance of the diseased tissue. During the formative period of a pulmonary abscess there is an extensive zone of edema and some extravasation of blood around the area. When the abscess is well developed there is a central cavity of considerable size, sometimes small and at other times very large, the wall of which is composed of more or less necrotic epithelial tissue. In more advanced cases of longer duration, the wall of the abscess cavity may be several millimeters thick and composed of dense fibrous tissue. Usually several smaller abscesses are present in the zone surrounding the main abscess. Blood vessels are sometimes observed to cross through the cavity unsupported by epithelial tissue, giving the impression of ropes or cords which have been strung across. Sometimes they are thrombosed but when not they may give rise to the sudden massive hemorrhages which often complicate the condition of pulmonary abscess.

A common complication of pulmonary abscess is empyema from rupture of the abscess in the pleural cavity with the formation usually of pyopneumothorax because air also escapes into the pleural cavity. Brain abscess and meningitis, mediastinal abscess, and suppurative pericarditis are all complications which occur with some frequency. Hemorrhage is sometimes severe enough to be fatal. Extension of the infection to other parts of the lung is a frequent cause of death in such cases. Clubbing of the fingers and toes and amyloid degeneration are complications seen with chronic pulmonary abscess but seldom



Fig. 14. Agenesis of the lung. Congenital abscess of the left lung in a 16-year-old boy. He has no pulmonary symptoms. Medical help sought at an early age because of the external chest deformity. Note the marked shift of the heart to the left, and the stump of the left main bronchus.

necessary for cure in the more localized types of cystic disease. In the diffuse form, the patients usually do not survive.

Variations may occur in the location of the fissures and even in the number of lobes in each lung. Incomplete interlobar fissures are not uncommon. An azygos lobe may be formed by an abnormal course of the azygos vein through the substance of the right upper lobe rather than the usual mediastinal course. It occurs in slightly less than 1 per cent of the population. The need for recognition is primarily to avoid confusion with other conditions. Occasionally, an azygos lobe may be the seat of tuberculous or cancerous disease.

Variations in the pulmonary arterial and venous supply are very common. The tremendous upsurge in pulmonary resection in recent years has made necessary the accurate anatomic documentation of all possible variations. The studies of Kent and Blades (10), Boyden (11), and others have been most valuable in this regard.

Pulmonary Abscess. Pulmonary abscess may be defined as the gross destruction of lung tissue resulting from a parenchymal infection. The various etiologic factors may be grouped under six headings: 1. surgical operations; 2. aspiration of foreign material; 3. pneumonia; 4. wounds of the lung; 5. carcinoma of the bronchus, lung, and esophagus; 6. miscellaneous factors.

1. Of the surgical operations, those performed in the mouth are especially dangerous. Particularly is this the case with the operation of tonsillectomy performed under general anesthesia, although actually, as was shown by Moore, the chance of the development of a pulmonary abscess is only about one in 2,500 to 3,000 tonsillectomies. If the operation of tonsillectomy is performed under a deep general anesthesia, the chance of developing pulmonary abscess is greater probably because there is likely to be aspirated into the lung a larger amount of blood and pus than if the normal swallowing and coughing reflexes are preserved.

2. Again, it is well known that the aspiration of peanuts is likely to be followed by an extensive bronchitis, with the subsequent development of more or less extensive gangrene because of the irritating qualities of the fatty acids formed in the decomposition of the peanut.

3. Pneumonia is often stated as a frequent cause of pulmonary abscess. This statement is mainly due, however, to the fact that any inflammation of the lung in its early stages is likely to be diagnosed under the inclusive term of pneumonia. The term pneumonitis would be preferable. Actually, there is little evidence that ordinary lobar pneumonia is very often the precursor of pulmonary abscess. On the other hand, streptococcal pneumonia, especially that type which was present in the severe epidemics of 1917 and 1918, is often associated with pulmonary abscess.

4. Wounds of the lungs seldom produce an abscess.

5. Carcinoma of the bronchus is nearly always associated with single or multiple pulmonary abscesses at some time in its course. It is a matter of the greatest importance to bear in mind because a pulmonary abscess in a person of middle age, which has come on with no apparent reason, is often due to a carcinoma.

variety. The fever in the severe cases may reach 104° to 105° F. After drainage becomes established, either spontaneously or otherwise, the fever will diminish. In the presence of rapidly developing gangrene, the symptoms of prostration may be very marked. The sputum, although scanty in the formative period of the abscess, may later become profuse. In some cases more than 500 ml. of pus may be expectorated in 24 hours. The color is not characteristic, but it is not uncommon for the sputum to show streaks of blood and sometimes a considerable hemorrhage occurs. The presence of a foul odor is dependent upon active putrefaction.

It is desirable, of course, always to examine the sputum for tubercle bacilli and for other specific types of infection, such as actinomyces. The bronchoscope is of value in ruling out the presence of a foreign body or endobronchial tumor. It also helps to locate the abscess and moreover it sometimes facilitates the drainage of the tracheobronchial tree. For all of those reasons, a bronchoscopic examination should be recommended in every case of pulmonary abscess. The use of an aspirating needle in cases of suspected pulmonary abscess is dangerous because of the possibility of creating an empyema. It is always important to remember that the abscesses may be multiple and that consequently the localization of a single one does not necessarily complete the diagnosis.

The *treatment* of a case of pulmonary abscess will vary considerably according to the conditions which are present (12). Because of the effectiveness of the various chemotherapeutic and antibiotic agents now available, many more abscesses go on to resolution and/or spontaneous endobronchial evacuation and cure than formerly. The first consideration is the prompt administration of adequate doses of an antibiotic or antibiotics to which the infecting organisms are sensitive. Close x-ray scrutiny is kept on the status of the process and with the development of a fluid level the patient should be bronchoscoped. One is able in this manner to bring about improved endobronchial drainage with resultant improvement. Postural drainage, i.e., having the patient lie over the bedside with the head and chest dependent, will assist in the evacuation of pus. In the majority of cases, such a regimen will eventuate in either spontaneous resolution with healing and recovery or a "settling down" into a chronic state. The latter is characterized by a residual cavity or an area of infiltration which persists. In either event, the patient continues to cough and raise purulent sputum even though the systemic manifestations will have greatly abated. This status is generally reached from four to six weeks after onset and indicates that no further improvement may be anticipated from nonsurgical measures. Such patients are best treated by removing the involved lobe or portion of lobe (Fig. 17). An occasional case will require drainage because of age, debility or the rapid development of a cavity with marked evidences of sepsis.

Lung abscess remains a serious disease but with the skilful application of modern methods the mortality should not exceed 5 per cent.

Hydatid Disease (Echinococcus Cysts). Because of its rarity in this country, no extensive discussion of this condition will be given here. Echinococcus infections have



Fig. 17. Lung abscess treated by lobectomy. This 27-year-old man developed pneumonitis of left lower lobe, followed by increased production of purulent sputum. Left lower lobectomy was done after a period of medical treatment.

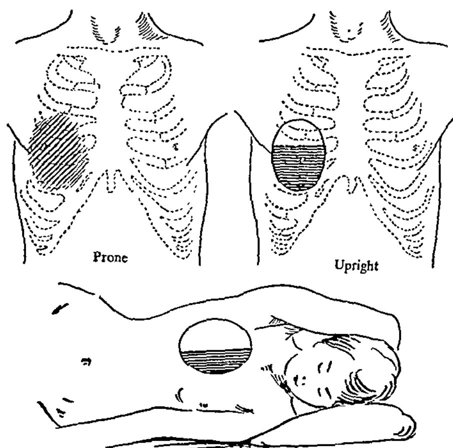


Fig. 16. Diagram to show the advantage of change in position in the demonstration of the fluid level in a suspected abscess cavity by the use of the roentgen ray. (From Graham, Singer and Ballon. Surgical Diseases of the Chest, Lea & Febiger.)

with the acute disease. In any case of chronic pulmonary abscess, more or less marked bronchiectasis is probably always present.

The principal *symptoms* of pulmonary abscess usually occur in the following order of frequency: productive cough with the sputum often blood stained, fetor, fever, chills, sweats, pain in the chest, and loss of strength and of appetite. The formative stage of pulmonary abscess usually has a duration of a few days to two or three weeks. There may be no sputum during that time. As soon as a communication with a bronchus is effected, foul expectoration occurs. In acute cases, the patient is sometimes able to indicate the site of the abscess by the location of the pain. Empyema may complicate the picture early in the disease. Mediastinal abscess and brain abscesses, however, are usually later complications. Clubbing of the fingers and toes is a complication of the chronic form of the disease.

In the examination of the patient, x-ray films are of paramount importance. Ordinary physical examination may reveal the presence of a large cavity but the accuracy of diagnosis is much greater with suitable x-ray examination. The most important finding in the x-ray examination is the presence of a fluid level within the lung field. In many cases, however, the fluid level cannot be demonstrated and in such cases only a region of induration will be detected. In searching for a fluid level it is of the greatest importance to have the patient in such positions as will demonstrate it. If the patient lies on the film either prone or supine, the level will almost certainly fail to be seen. It is necessary to have the patient either in a horizontal position with the diseased side uppermost, or in a sitting position (Fig. 16). Films taken in both of the two latter positions are preferable to a single one. There is usually a leukocytosis of approximately 20,000 with a relative increase in the polymorphonuclear

the responsible etiological factor, there is no very convincing evidence that any of them, except cigarette smoking, deserve much consideration. It is true that for many years a high incidence of the disease has been recognized in the Schneeberg miners whose work results in the production of large quantities of radioactive dust containing sharp-angled particles rich in arsenic. But this set of conditions involves only a small number of workers and cannot possibly have any bearing on the widespread increased incidence of bronchiogenic carcinoma. The same can be said of the more recently discovered high incidence of the disease in chromate workers (16).

There is much evidence, however, to indicate that excessive cigarette smoking may be a very important factor. Although some cigarettes were smoked in the last century, the extensive use of them began at about the time of World War I. The possibility of an etiological relationship has been suggested by many, especially Tylecote (1927), and Ochsner and De Bakey (17) but what was needed was at least a large scale statistical study of patients with lung cancer. Two such studies have now been made independently, one by Wynder and Graham (18), and the other by Doll and Hill (13) of England. Wynder and Graham's study was based on 684 proved cases, and that of Doll and Hill on 709 cases. Both were published in 1950. They came to the same conclusions, namely, that in practically all cases in men there is a history of excessive cigarette smoking over a period of more than 20 years and that it is very rare to find a case in a nonsmoker. Doll and Hill even state that above the age of 45 the chance of developing bronchiogenic carcinoma is approximately 50 times as great among those who smoke 25 or more cigarettes a day as among nonsmokers. Probably the carcinogenic agents reside in the tars in the cigarette smoke. The type of carcinoma chiefly related to smoking is the squamous (epidermoid) or an undifferentiated form.

The adenocarcinoma has characteristics which seem to make it a totally different tumor from the squamous variety, not only in respect to its microscopic appearance. From the statistical studies, it seems to have little or no relationship to cigarette smoking, and its incidence is about as great in females as in males. Presumably, therefore, the etiological factors for this carcinoma differ from those thought to be important in the development of squamous (epidermoid) carcinoma.

Metastases. Bronchiogenic carcinoma spreads, as does cancer elsewhere, into the neighboring lymphatics and may travel into both the mediastinal nodes and outward toward the periphery of the lung. The cartilages in the walls of the larger bronchi seem to offer the same amount of protection against the spread of the growth as does the cartilage in the larynx. There is, therefore, not an early extension through the wall of the bronchus unless the tumor arises in one of the smaller bronchi without cartilaginous walls. Tuttle and Womack (1934), in a study of the cases in the Barnes Hospital, showed that metastasis through the blood stream into distant organs occurs more often when the carcinoma arises in a smaller bronchus near the periphery of the lung than when it originates in one of the larger bronchi in the hilus region. Of particular importance in regard to the question of metastasis is the frequency of secondary deposits in the brain (about 25 per cent), in an adrenal (about 30 per cent), and in the kidney (about 25 per cent). Others have also noticed the curious frequency with which bronchiogenic carcinoma metastasizes to the adrenal glands. Sometimes the first notable symptom is due to a distant metastasis, as in the brain.

Symptoms and Diagnosis. There are no pathognomonic symptoms. When it is recalled that the tumor usually arises in a large bronchus, it will be realized that the early symptoms are those of bronchial irritation which results in cough and expectoration. As the cancer becomes ulcerated, blood will appear in the sputum. This is seen most commonly only as streaks. A large hemorrhage is rare. In most cases, as the tumor grows, the symptoms and signs of atelectasis of a lobe or a segment of a lobe appear because of bronchial obstruction. The patient then will have not only cough and sputum but a feeling of discomfort and tightness which may amount to actual pain in his chest. Sooner or later in almost all cases, infection will occur in the atelectatic portion of lung. To the other symptoms there will then be added those of

been discussed elsewhere in this book in more detail. From the standpoint of the thorax, it is important to realize that, next to the liver, the lung is the most frequent site of hydatid cysts but they are much less frequent than in the liver; for example, the condition occurs with a frequency to the liver about seven times greater than in the lung.

Many pulmonary hydatid cysts produce no striking *symptoms*, even if they may be very large. Cough is perhaps the most common symptom produced, but unless the cyst is ruptured into a bronchus, the cough is not severe. It is intermittent and accompanied by very little expectoration. If, however, a rupture into the bronchial tree has occurred, the contents of the cyst will be expectorated in the sputum. Frequently, there also will be hemoptysis of varying degrees. If the cyst is near the diaphragm, coughing is likely to be more pronounced even if it has not yet ruptured into a bronchus. The amount of dyspnea will be determined largely by the size of the cyst and the amount of pressure which it produces. The most common site of the cyst is in the right lower lobe. One of the principal dangers of rupture into the bronchial tree is that of severe allergy. This may be so severe as to cause death.

The *diagnosis* of pulmonary hydatid cyst is made on the finding of a spherical shadow by roentgen examination and by the principal laboratory methods of diagnosis which have been discussed elsewhere, such as 1. the intradermal test of Casoni; 2. the complement fixation test of Weinberg; 3. the examination of the blood for the presence of an eosinophilia; and 4. the examination of the contents of the cyst and of the sputum for the characteristic hooklets and fragments of cyst membrane. It is dangerous to aspirate a cyst because of the possibility of a severe allergic reaction from absorption by leakage into the lung or thoracic cavity.

The *treatment* of pulmonary hydatid disease is surgical excision wherever possible. This may be done by dissecting out the cyst itself or by removal of the diseased lobe. Care should be taken to avoid rupturing the cyst during removal because spillage of the contents can lead to anaphalactoid shock and death. Very large or tense cysts should be aspirated before removal.

TUMORS OF THE LUNG

Carcinoma. The most important tumor of the lung is carcinoma. Practically all, if not all, carcinomas arise in a bronchus. For that reason, primary carcinoma of the lung is usually called bronchiogenic carcinoma. Although some pathologists have classified this tumor into many varieties depending upon the morphologic appearances seen microscopically, the most common types are squamous or epidermoid, undifferentiated, and adenocarcinoma. The so-called round cell carcinoma can probably just as well be included in the undifferentiated group as to demand a separate classification.

Incidence. The incidence of bronchiogenic carcinoma has increased enormously in the last 40 years. Doll and Hill (13) found that in the 25 years between 1922 and 1947 in England and Wales the number of deaths ascribed to this condition increased fifteenfold. In the United States, there was an eightfold increase between 1914 and 1935. Cancer of the lung has increased so much during the past several years that it is now the second most common cancer in males, being surpassed only by cancer of the skin. In 1956, there were 31,000 cases (estimated) in the United States (14).

The condition is much more common in males. Various published statistics show its incidence to be from 10 to 20 times more frequent in males than in females. It occurs most *commonly in the sixth* decade of life. Most cases belong to the microscopic classification of squamous (epidermoid) or undifferentiated carcinoma. In our own series at the Barnes Hospital, 95 per cent are in those categories and adenocarcinoma comprises most of the remainder.

Etiology. The enormously greater incidence of bronchiogenic carcinoma in males suggests that perhaps the female sex has a relative immunity against it. But Kemler and Graham (15) found that human tumors from male patients could be transplanted with equal ease into the eyes of guinea pigs of both sexes, using Greene's technic. Evidently, therefore, female sex factors have nothing to do with the greater incidence in men.

Although the exposure to the influence of many different agents has been proposed as

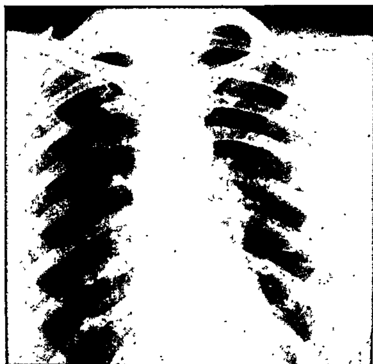


Fig. 18. (Cont.) X-ray variability of bronchogenic carcinoma. Above, superior sulcus tumor, right apex. This tumor involved the brachial plexus, causing shoulder pain. Below, cancer developing in the right middle lobe in a patient being treated for proven tuberculosis of right upper lobe.



Fig. 18. X-ray variability of bronchogenic carcinoma. Above, left hilar mass. This form is the most easily recognized on x-ray. Below, complete atelectasis of left lower lobe due to endobronchial cancer.

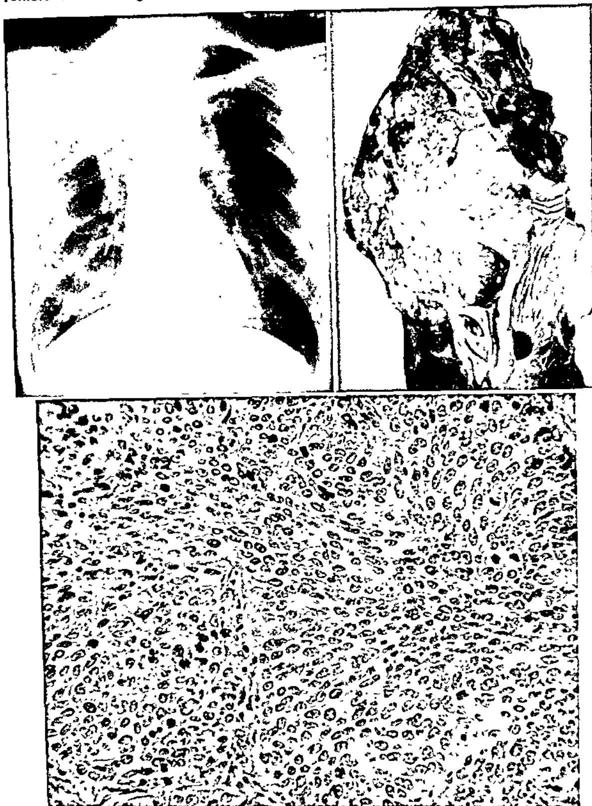


Fig. 19. Epidermoid carcinoma right upper lobe. This 55-year-old patient complained of cough and minimal weight loss. Because of the x-ray appearance, above left, tuberculosis was suspected. All diagnostic studies were negative. At operation a tumor of the right upper lobe was found which completely blocked the bronchus. Above right, shows the cut surface of the tumor. Below, a photomicrograph showing the histologic picture of a poorly differentiated epidermoid cancer.

pulmonary infection. Late occurrences are the involvement of nerves, such as the phrenic, the recurrent laryngeal, the brachial plexus, and the nerves of the chest wall. When the latter nerves are invaded by the cancer the pain is generally severe.

Ordinary x-ray examination (Fig. 18), although important, will usually reveal only an area of atelectasis and sometimes evidence of complications, such as pulmonary abscess and pleura effusion. In only a small percentage of cases does the x-ray examination reveal the tumor itself and then usually only one which is located peripherally. Bronchography with the injection of lipiodol is sometimes helpful in locating the bronchial obstruction. Bronchoscopy with biopsy of a suspicious lesion is the most important single diagnostic procedure, but it gives positive results in only slightly more than half the cases because many of the tumors are beyond the reach of the bronchoscope. The chance of a positive diagnosis can be increased to about 80 or 85 per cent by a combination of bronchoscopy and the cytological examination of bronchial washings and sputum by an expert. There will remain from 15 to 20 per cent of cases in which an exploratory operation will be required in order to establish the diagnosis.

Treatment. At present, the only successful treatment of bronchiogenic carcinoma is by surgical removal (Fig. 19). In general, the operation of choice is total pneumonectomy with wide removal of tracheobronchial lymph glands. However, some patients with poor respiratory reserve because of advanced age, emphysema, or poor cardiac function may be made "respiratory cripples" by the loss of a whole lung. In such cases, it is probably wiser to be less radical and to remove only the involved lobe. It is now possible by suitable tests of respiratory function to determine in advance whether or not the patient is likely to be badly crippled by the loss of a lung. The immediate operative mortality for pneumonectomy in cancer patients is now only about 5 or 6 per cent. The percentage of five-year survivals after the operation is encouraging but undoubtedly it will become much higher when patients come earlier to the surgeon. In a study completed in 1957 of 158 cases of total pneumonectomy performed at Barnes Hospital, 34 or 21.5 per cent have survived more than five years after surgery. The first patient to undergo successful pneumonectomy for carcinoma is alive and well 24 years after operation, despite the fact that two lymph nodes were invaded by cancer. The percentage of five-year survivals after pneumonectomy quoted above is similar to that obtained in other chest surgery clinics. Thus, for example, Overholt and Schmidt (19) had 24.4 per cent and Wiklund (20), in a recent report from Crafoord's clinic at Stockholm, stated that there were 25 per cent five-year survivals in their cases.

One of the most discouraging aspects of bronchiogenic carcinoma is the fact that, although the condition is curable by surgical removal, less than 50 per cent of the patients reach the thoracic surgeon at a time when there is any possibility of performing a radical resection. In our own cases a pneumonectomy has been carried out in only about 30 per cent of those in whom a positive diagnosis was established. The principal reason for the delay seems to be that physicians are too much inclined to make a diagnosis of atypical or virus pneumonia and to treat the patients with antibiotics. If the complicating infection is thereby improved, an unjustified optimism occurs and still more valuable time is lost in establishing the diagnosis of cancer.

Bronchial Adenoma. There is another bronchial tumor, much less common than the epidermoid bronchiogenic carcinoma, which usually arises in a major bronchus. It may have either a pedicle or a sessile attachment to the bronchial wall. Sometimes part of the tumor is intrabronchial and the rest extrabronchial with perhaps the largest portion outside the bronchus. These tumors are usually roughly spherical and on bronchoscopy they appear pink because of their vascularity. They may produce marked bronchial obstruction with resulting atelectasis, bleeding, and infection. They are found in both sexes about equally and at any age, even in childhood. A biopsy may reveal one of several more or less characteristic features, of which the most common is a collection of cells with small amounts of cytoplasm and relatively large nuclei. A section may closely resemble atelectatic fetal lung. Often the cells appear to be in cords and sometimes to have a glan-

SURGICAL ASPECTS OF PULMONARY TUBERCULOSIS

It is remarkable that so rational an idea as the employment of surgical measures for the treatment of pulmonary tuberculosis should have been so long in establishing itself. As far back as 1820, James Carson of Liverpool proposed the use of artificial pneumothorax. Apparently, however, the first actual use of artificial pneumothorax in this disease was made by Carlo Forlanini in 1888. Even then, the method did not become of general use until it was popularized in the early part of this century by Brauer. Today the combination of medical and surgical treatment is restoring more tuberculous patients to useful society than ever before.

Pulmonary tuberculosis is a disease characterized by the formation of cavities within the lung. Nature's process of obliteration of any cavity in the lung is by immobilization and more or less collapse of the affected side of the chest by drawing the ribs together, by pulling up the diaphragm, and by pulling the mediastinal contents over to the affected side. When these phenomena can occur to a satisfactory degree the cavity will often be spontaneously obliterated. There are many cases, however, in which nature's efforts fail because the structures to which the lung is attached by adhesions are sufficiently unyielding to prevent the spontaneous collapse of the cavity. In the preantibiotic era, the basis of all surgical methods used in the treatment of pulmonary tuberculosis was the theoretical assistance given to nature by overcoming some of the resistance to the spontaneous contraction of the lung. These methods, therefore, are commonly spoken of under the general term of *collapse procedures*. The simplest one is the creation of an artificial pneumothorax. Gradually, however, as the utility of that procedure became more and more realized, other procedures were devised for the purpose of promoting an adequate collapse of the lung. Thus, ribs were removed from the chest wall in order to make the wall more yielding and therefore more likely to be pulled in by subsequent contraction of scar tissue. Also, operations were devised, based on the principle of interrupting the phrenic nerve so that the diaphragm on one side would become paralyzed and ascend readily into the thorax, thereby assisting in the collapse of the lung.

Tuberculosis is a disease characterized not only by the frequent occurrence of cavities within the lung but also by the development of empyema. In the latter instance, of course, the condition is again one of cavity although the cavity is pleural instead of pulmonary. Many of the principles, therefore, of collapse and compression which are useful for the obliteration of pulmonary cavities are likewise useful for the treatment of tuberculosis empyema.

As experience with collapse methods of treatment became more extensive, it was realized that such methods were applicable not only to cases in which there were demonstrable pulmonary cavities but also that many patients improved after such methods of treatment even when demonstrable cavities were not present. Now it is well known that the immobilization and shrinkage of the lung produced by methods of collapse therapy diminish the toxic absorption from the active lesions in the lung by diminishing the circulation of lymph, and also produce a chronic passive hyperemia of the lung. These two factors result in limitation and demarcation of the affected areas of lung tissue and also in the proliferation of connective tissue. An exudative process is, therefore, converted into a productive one. Moreover, collapse therapy also facilitates and increases the amount of expectoration which is the natural method of drainage of the debris from the cavities within the lung.

Since the development of the specific antibiotics, such as streptomycin, for the medical control of tuberculosis, the use of collapse procedures has largely been replaced by excisional procedures, whereby the diseased tissue is not compressed, but is removed completely from the body. In patients who cannot withstand major extirpative surgery for some reason or other, the collapse procedures may be helpful.

Artificial Pneumothorax. Formerly this procedure was widely used and was one of the most valuable adjunctal methods of therapy. With the advent of streptomycin, para-amino salicylic acid, and pneumoperitoneum the

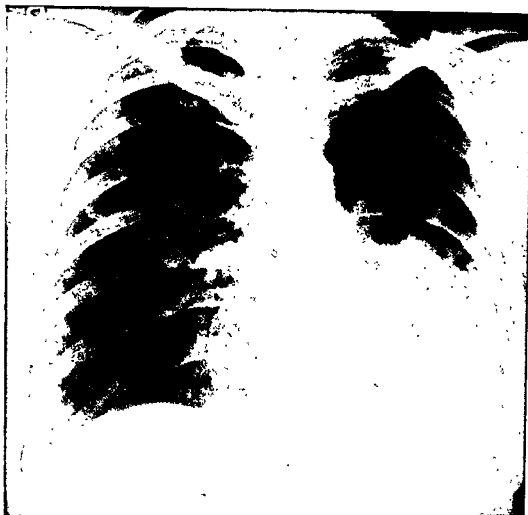


Fig. 20. Alveolar cell carcinoma. This 55-year-old woman complained of increasing dyspnea and the production of large amounts of clear sputum. The diagnosis was made by sputum cytology. Note the beginning involvement of the right upper lung by the process.

dular structure. The tumors often pursue a benign course for years, but Womack and Graham (1938) showed that many of them become malignant and produce regional and distant metastases. All of them, therefore, are to be regarded as potentially malignant. Often it is impossible to be sure from the microscopic appearance alone whether or not the tumor has become malignant, and mitotic figures are rarely seen.

The treatment of the so-called bronchial adenoma is surgical. While the tumor is still in a benign stage it can sometimes be handled by opening the bronchus, removing the growth, and closing the bronchus again. Usually, however, because of the presence of infection it is more advisable to perform a lobectomy. If, however, there is evidence of local invasion or involvement of regional lymph nodes pneumonectomy is to be preferred.

Alveolar Cell Carcinoma, Bronchiolar Carcinoma. The rare type of cancer of the lung, which is designated by one of these names, is distinguished from the common varieties by apparently arising in the pulmonary parenchyma instead of in a bronchus. It bears a close resemblance to the South African sheep disease known as "jagziekte." Also, there are many similarities to the cancer of the lung which occurs in mice. The prognosis is very bad in spite of radical surgery. Reports of cases will be found in articles by Delarue and Graham (21), Stephens and Shipman (22), and by Storey (23) (Fig. 20).



Fig. 22. Pulmonary resection for tuberculosis. This 36-year-old man had been treated for fibrocavitary tuberculosis of the left upper lobe for three years. Treatment included antituberculous drugs, left pneumothorax, and left phrenic nerve crush. Sputum was still positive at the time of left upper lobectomy. Left, shows lesion prior to surgery. Right, film one and one-half years after operation. Patient is sputum negative and clinically well.

performed. In those cases with unilateral multilobar cavitary disease or in those cases where stenosis of the main stem bronchus exists, it will be necessary to do a total pneumonectomy. Giant cavities which are notoriously hard to collapse by thoracoplasty are best treated by lobectomy (Fig. 22). Lesser degrees of involvement will be amenable to so-called segmental resections. One of the most common indications for pulmonary resection in tuberculosis is in that group which is loosely called "thoracoplasty failures." These are cases in which an apparently adequate thoracoplasty has failed to produce cavity closure and sputum conversion. Such cases are subjected to the removal of the lobe or the lung as required by the pathology (25). Tuberculomas are removed either by a simple "wedge" resection or by a segmental resection.

The results of excisional surgery are now sufficiently extensive and the follow-up of cases long enough to state unequivocally that resection in tuberculosis far surpasses any type of collapse therapy. Surgical removal of the diseased tissue allows earlier return to activity and a lower relapse rate. In properly selected operative cases, it is possible to achieve arrest of the disease in 85 to 90 per cent of the patients.

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number of pneumothoraces has declined markedly.

Plombage. This procedure consists in the direct application of pressure exerted on the parietal pleura against a cavity in order to assist in its obliteration. Materials that have been used for this purpose are gauze packs, inflatable rubber bags, paraffin, lucite balls, and polyvinyl sponge. The chief dangers in the placement of any type of foreign material near tuberculous lung tissue are infection and migration of the plombe. The best results reported to date have been with the extraperiosteal placement of lucite spheres. It is probable that all types of plombage procedures will be discarded in favor of excision.

Extrapleural Thoracoplasty. The modern present-day operation of thoracoplasty has gone through a period of evolution, starting with operations for the collapse of cavities by the removal of ribs. Because of the extensive accumulation of experience with this operation, it is now possible to state rather dogmatically that the operation is not usually effective unless considerable portions of the upper ribs are removed. The modern operation is entirely extrapleural. It is divided into stages separated by intervals usually of at least two or three weeks and it is carried out through a posterior incision. One of the essential requisites that has been learned is that to be effective in collapsing the upper part of the lung, it is necessary that there should be a dropping downwards of the pulmonary apex. This cannot be expected to occur unless large segments amounting usually to practically the entire lengths of the first and second ribs are removed. If such an operation is performed, ordinarily it is not so necessary that very long segments of the lower ribs be removed, although it is customary in a case of complete unilateral thoracoplasty to remove the lower ribs from the corresponding transverse processes to at least the posterior axillary line and often to the anterior axillary line. It is customary also, in most cases, to begin the operation with the removal of the first two or first three ribs. This constitutes the first stage. Two or three weeks later, three or four more ribs are removed; and two or three weeks after that, the remaining ribs including the tenth and sometimes even a portion of the eleventh ribs are removed (Fig. 21). In other cases in which the tuberculosis is limited to the upper part of the lung, a total thoracoplasty is much less commonly performed than formerly because it is recognized now that removal of the upper three or five ribs is often sufficient to accomplish the desired result. This procedure leaves the function of the lower part of the lung relatively uninterrupted. Thoracoplasty is indicated less and less, and in the author's opinion will soon be a rarely used procedure.

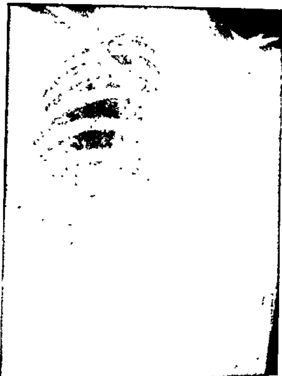


Fig. 21. Extrapleural thoracoplasty. This 19-year-old woman had a seven-rib, three-stage thoracoplasty on the left side for extensive cavitary disease of the left upper lobe. She remained well for five years but subsequently became sputum positive again, and required a left pneumonectomy before her disease was permanently controlled.

Pulmonary Resection in Tuberculosis. As mentioned previously, the tendency in general now is to do a total extirpation of the pulmonary disease whenever possible (24). The development of more refined technics and the protection afforded by the antibiotics, particularly streptomycin, has made possible the extirpation of infected pulmonary areas without either local or general dissemination of the disease. The extent of the disease will, of course, determine the type of resection to be

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SURGERY OF CONGENITAL CARDIOVASCULAR DISEASE

Michael E. De Bakey, Denton A. Cooley,
George C. Morris, Jr., and E. Stanley Crawford*

INTRODUCTION TO SURGERY OF CARDIOVASCULAR DISEASE

Few areas in medicine have exhibited the phenomenal progress that has taken place in the field of cardiovascular surgery during the past few decades. Indeed, the advancements made during the past decade alone far surpass all previous efforts in this field of surgery. A number of recent developments in cardiovascular surgery constitute truly brilliant achievements reflecting vigorous effort and intensive investigation. One of the most striking features of this advancement, and undoubtedly an important factor underlying its attainment, has been the bold ingenuity and aggressive approach characterizing the surgical attack on certain cardiovascular problems, the gravity of which has long been recognized. Lesions which only a few years ago were considered hopeless are now amenable to curative surgical treatment. Of equal, if not of greater, significance is the fact that these intensive investigative endeavors have led to additional knowledge and better understanding of the underlying anatomic and physiologic disturbances of these diseases.

In the main, surgical treatment in cardiovascular disease is directed toward correction of the defect by mechanical means. This may be accomplished by one of several approaches, the choice depending upon the nature of the lesion. In some instances, for example, it is possible to remove the lesion with elimination of both anatomic and physiologic disturbances. This is exemplified by the procedures of division and suture of a patent ductus arteriosus, excision with end-to-end anastomosis of coarctation of the aorta, and resection with graft replacement of aneurysm of the aorta. In other instances, a more indirect approach must be employed, in which the

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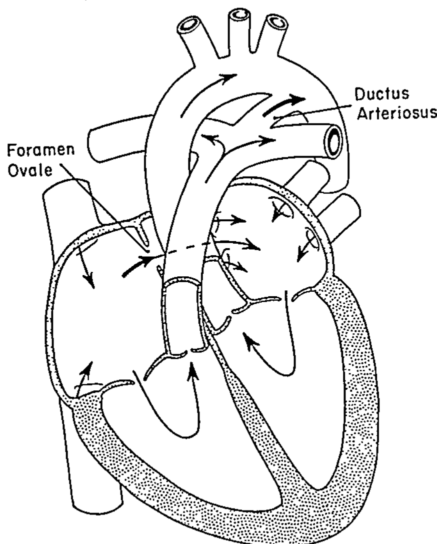


Fig. 1. Drawing of fetal circulation showing usual course of blood flow. Placental blood is shunted away from pulmonary circulation through the foramen ovale and the ductus arteriosus, both of which normally close after birth.

artery persists as the ductus arteriosus. Both the fourth and the sixth arches originate from the aortic sac, which connects with the bulbus cordis. Development of an aortic septum divides the common trunk into aorta and pulmonary artery. Ultimate fusion of this septum centrally with the advancing interventricular septum leads to final closure of the ventricular septum and separation of the heart into right and left sides.

Upon completion of development of the fetal heart, the circulation follows a definite pattern. Since oxygenation of fetal blood is provided by the maternal placenta, the fetal lungs are functionless until birth, when respirations commence and the lungs are inflated. Placental blood returning to the right side of the heart may bypass the pulmonary circulation through the foramen ovale or the ductus arteriosus Botalli (Fig. 1). Persistence of these structures, although not representing true cardiac anomalies, may lead to physiologic disturbance in the heart if spontaneous obliteration does not occur. Closure of the ductus arteriosus begins immediately after birth and the process is usually complete by the end of the second month. A patent foramen ovale is present at birth but is guarded by a valvelike arrangement of membranes, which permits blood to flow from the higher pressure right atrium to the left atrium. After birth, as this pressure relation-

operative procedure is designed to provide beneficial alteration of physiologic disturbances produced by the lesion. This is exemplified by the Blalock-Taussig operation for tetralogy of Fallot and the bypass grafting procedure for certain types of thrombo-obliterative disease of the aorta.

Although truly impressive progress has been made in this field of cardiovascular surgery, there still remains a host of diseases for which no satisfactory method of surgical treatment is yet available. The vigor and intense activity characterizing the investigative attack upon these conditions are highly gratifying and portend further advancement in this area of endeavor. It is manifestly impossible to discuss all phases of the subject, and primary consideration must be given to the more significant accomplishments and trends of development. For purposes of convenience the diseases included in this presentation have been classified into two broad categories according to their origin: congenital (Ch. 37), or acquired (Ch. 38).

Congenital malformations of the heart occur in many forms, either as a single anomaly or as a combination of anomalies. Since the basic and most important embryologic phenomena which ultimately lead to development of the heart and great vessels occur during the first six weeks in the intrauterine life of the embryo, many malformations are present long before birth. Such anomalies may be considered true cardiac malformations and thus represent a true developmental defect. On the other hand, certain normal structures in the embryonic heart which provide for the requirements of intrauterine life and the dependency upon placental circulation may persist after birth, such as a persistent patency of the ductus Botalli or foramen ovale (Fig. 1). Although these may lead to physiologic disturbance in extrauterine life and may not be actual congenital cardiovascular malformations, nevertheless, such anomalies must be considered along with the true congenital anomalies.

Accurate understanding of the morphologic anatomy and physiopathologic aspects of congenital malformations of the heart must be derived from a basic knowledge of embryologic and fetal circulation. By the third week of embryonic life the primitive cardiac tube has appeared near the cephalic end of the embryo. Growth of the tube occurs rapidly, producing convolutions and bulbous segments, one known as the bulboventricular loop and another a dilated segment which forms a common atrium from the left and right sinus venosus. The atrium lies above and behind the ventricles and is connected by a common atrioventricular canal. The anlage of the separate cardiac chambers is discernible by the fourth week. A muscular ridge appears in the floor of the bulboventricular canal and progressively extends centrally to form the muscular portion of the ventricular septum. By the fifth week, great progress in cardiac differentiation has occurred and the interatrial septum has been formed. During the next week, the primitive opening (ostium primum) at the inferior margin of the septum closes and the secondary opening (ostium secundum) appears and forms the foramen ovale. By the sixth week, the endocardial cushions developing in the region of the atrioventricular junction and converging centrally start the obliteration of the atrioventricular canal and also form the anlage of the mitral and tricuspid valves. The cushions meet the advancing muscular interventricular septum and fuse finally at a point which ultimately is known as the membranous portion of the interventricular septum. The endocardial cushions also fuse with the primitive interatrial septum and contribute to obliteration of the ostium primum. This completes the division of the heart into four chambers.

Simultaneous with the intracardiac development is rapid development of the vascular connections to the remainder of the embryo. The principal arterial connections of the heart are derived from a complex of primitive aortic arches, six in number. As the heart develops and moves caudally in the embryo, the aortic arch is derived from the fourth branchial arch and the pulmonary artery from the sixth (Fig. 2). Normally the sixth left branchial arch distal to the pulmonary

chambers, although the congestive effects are usually less rapid because of the compensatory forces which maintain cardiac function and delay onset of cardiac decompensation.

Method of Diagnosis. In diagnosis of congenital malformations of the heart, an accurate history is of utmost importance. Exact definition of the mode of onset of symptoms, date of appearance of symptoms, such as cyanosis and exertional dyspnea, and careful description of the disabling effects are often of vast importance in arriving at the final diagnosis. Careful physical examination, noting the presence of cyanosis, clubbing of the nails, location and nature of murmurs, and presence and character of pulses in all extremities, and so forth, is imperative in such cases. Laboratory studies including complete hemogram are useful, particularly since polycythemia accompanies most lesions associated with cyanosis.

Special diagnostic procedures of great importance have been developed in diagnosis of congenital cardiac defects; these include (a) roentgenography and fluoroscopy, (b) electrocardiography, (c) cardiac catheterization, and (d) angiocardiography and aortography.

ROENTGENOGRAPHY AND FLUOROSCOPY. Typical configurations of the cardiac silhouette by radiographic technic are useful in the diagnosis of congenital lesions of the heart and the great vessels. In the anteroposterior projection and in the right and left oblique and lateral views, specific enlargement of cardiac chambers and vessels may be evident. Fluoroscopy may be even more valuable than roentgenography since artifacts due due to poor position of the patient and other causes may be eliminated. Abnormal pulsations in the pulmonary vessels and changes in cardiac contour during systole and diastole may aid in identifying the defect. Diagnosis may be facilitated by filling the esophagus with radiopaque substance, such as iodized oil or barium paste, and demonstrating the encroachments of the cardiovascular structures on the esophagus. Typical abnormalities may be demonstrated by this means, including a right aortic arch, aortic arch anomalies, and various conditions producing left atrial enlargement. Erosion of ribs by dilated, tortuous intercostal arteries is a characteristic finding in coarctation of the aorta.

ELECTROCARDIOGRAPHY. The usefulness of electrocardiography in diagnosis of congenital cardiac defects has increased enormously in the past few years and some anomalies may be identified by this means alone. Complete electrocardiographic studies must include precordial and unipolar limb leads. Ventricular and atrial hypertrophy may be demonstrated and the degree of cardiac strain assayed. Condition disturbances and findings concerned with cardiac rhythm may be detected and may lead to an ultimate precise diagnosis. Usually interpretation of the finer points in electrocardiography must be made by a cardiologist thoroughly familiar with congenital cardiovascular disease.

CARDIAC CATHETERIZATION. Perhaps the most important recently developed specialized diagnostic procedure in cardiac diagnosis is catheterization of the heart (Fig. 3). Right heart catheterization is performed by inserting special woven catheters of small diameter into a peripheral vein, usually the left antecubital, and threading the catheter centrally into the heart. In infants, the catheter must be inserted through an external jugular or saphenous vein in the groin. General anesthesia with Trilene or another volatile agent is usually required for catheterization in infants and small children to provide relaxation and cooperation of the patient, but in large children and young adults deep sedation only is necessary. Under general anesthesia it is possible, in children, to demonstrate physiologic changes in cardiac dynamics during inhalation of room air or oxygen. During catheterization the position of the catheter tip is checked repeatedly with the fluoroscopic screen. Recently the use of the electrode tip catheter connected to the electrocardiograph has been useful in following the course of the catheter. Left-to-right shunts are identified and localized by detecting the presence of oxygenated blood in the right heart. Oxygen content of separate blood samples may be used for this purpose, but the Van Slyke technic is slow and complicated and is being replaced by more practical

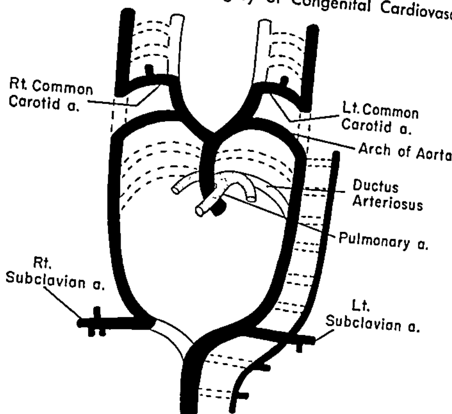


Fig. 2. Diagram showing developmental origin of the aorta, the major branches of the aortic arch, and the ductus arteriosus.

ship is changed, the valvelike foramen becomes obliterated or functionally closed. In about 10 per cent of individuals, a probe patency of the foramen ovale remains throughout life but is of no physiologic significance.

Physiologic Considerations. Congenital defects of the heart may produce a number of physiologic disturbances depending upon the nature of the lesion. For example, defects of the cardiac septa produce abnormal intracardiac shunts with blood shifting from a high-pressure to a low-pressure chamber. Shunts may be directed either from left to right or from right to left. Since pressures in the chambers of the left side of the heart are normally higher than in the corresponding chambers on the right side, an uncomplicated interatrial or interventricular septal defect leads to a so-called "left-to-right" shunt. Thus, blood of abnormally high oxygen content may be present in the right auricle, ventricle, or pulmonary artery. Defects with left-to-right shunts are not associated with cyanosis. If in addition to the septal defect another intracardiac anomaly exists, such as an obstructed tricuspid or pulmonary valve or underdeveloped right ventricle, the pressure in the chambers of the right side of the heart may be greater than the pressure in the corresponding chamber on the left, and a right-to-left shunt results. Under these circumstances, blood of low oxygen content is directed into the left atrium or ventricle, and when the blood gains access to the aorta and systemic arterial circulation, cyanosis results.

In another group of cardiac and great vessel anomalies, no vascular shunts exist and these lesions usually are manifested by the pressure effects and increased workload imposed upon the cardiac chambers. For example, valvular stenosis or atresia produces an obstruction to blood flow and increases the pressure and strain upon the chamber immediately proximal to the lesion. As the obstruction and intracavitary pressure increase, the effects may be transmitted to the lungs or liver, where congestion and edema may result. Underdevelopment of a cardiac chamber may lead to similar physiologic disturbance. Congenital valvular incompetence also increases the workload on the cardiac

and further useful diagnostic data are made available. Interpretation of the results of cardiac catheterization is sometimes difficult, and ultimate diagnosis may depend upon surgical exploration. Unquestionably these methods will be further developed and in the future other modifications in technics of cardiac catheterization will be introduced to improve diagnostic accuracy.

ANGIOCARDIOGRAPHY. Rapid injection of a radiopaque substance, usually an organic iodide solution, into the circulatory system provides a roentgenographic means of visualizing the chambers of the heart and great vessels (Fig. 4). A quantity, 1.0 ml. per kg. body weight of 70 per cent organic iodide solution (Urokon, Diodrast) is injected rapidly into a peripheral vein, using a large syringe either manually or mechanically operated. A special film changing device is used to expose films in rapid succession (usually six exposures per second is the maximum requirement) in order to follow the course of the solution throughout the heart, lungs, and aorta.

AORTOGRAPHY. Another technic of diagnostic importance in infants less than one year of age is retrograde aortography. In this technic, a small cannula is inserted in the left brachial artery and 5 to 15 ml. of 30 per cent iodized solution is injected (Fig. 5). The entire aortic arch may be visualized, and differential diagnosis of patent ductus arteriosus, truncus arteriosus, coarctation of the aorta, and other defects may be established. This technic is important in many instances, therefore, in excluding extracardiac lesions in the severely ill infant and providing information supporting the need for complete cardiac catheterization in establishing a diagnosis.

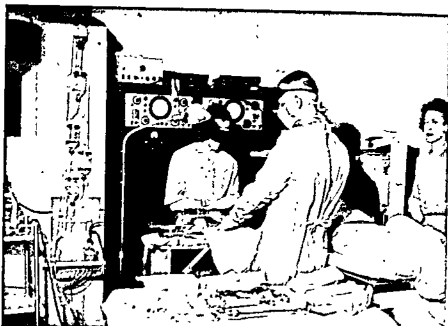
Classification. A number of classifications have been used for consideration of congenital cardiovascular defects. For the most part, these have been based primarily upon the presence or absence of cyanosis. With the growing emphasis placed upon physiologic and hemodynamic factors in congenital defects, a more useful classification would be based upon these vital factors. Thus, the following classification of the more common congenital cardiovascular defects is proposed:

I. Malformations not associated with a shunt
   A. Malformations of left side of heart
      1. Distal to mitral valve
         a. Coarctation of aorta
         b. Aortic vascular ring
         c. Aortic stenosis
         d. Endocardial fibroelastosis of left ventricle
         e. Anomalous origin of left coronary artery from pulmonary artery
      2. Proximal to mitral valve
         a. Congenital mitral stenosis
         b. Cor triatriatum
         c. Stenosis of pulmonary veins
   B. Malformations of right side of heart*
      1. Valvular or infundibular pulmonic stenosis
      2. Ebstein's malformation of tricuspid valve
      3. Underdevelopment of right ventricle
II. Malformations with a circulatory shunt
   A. Malformations with left-to-right shunt
      1. Atrial septal defect
      2. Ventricular septal defect
      3. Patent ductus arteriosus
      4. Aorticopulmonary septal defect
      5. Partial anomalous pulmonary venous drainage into right atrium
   B. Malformations with right-to-left shunt
      1. Transposition of great vessels
      2. Eisenmenger complex
      3. Tricuspid atresia
      4. Tetralogy of Fallot
      5. Pulmonary arteriovenous fistula
      6. Anomalous drainage of systemic vein into left atrium
   C. Malformations with combined shunts, predominantly left-to-right†
      1. True truncus arteriosus
      2. Single ventricle with increased pulmonary flow
      3. Total anomalous drainage of pulmonary veins into right atrium

The rapid and spectacular development of cardiovascular surgery has produced a significant effect upon the study of congenital heart disease. Lesions which just a few years ago were only of academic interest or considered to be rare medical curiosities now assume great importance. The incidence of many lesions now far surpasses previous estimates made during the presurgical era. Thus, it is important also to classify congenital defects on the basis of amenability to surgical repair or symptomatic relief.

* Right-to-left shunt may occur if foramen ovale is patent.

† Malformations with left-to-right shunt (Group A may with congestive heart failure manifest arterial unsaturation due to unsaturation of pulmonary venous blood and manifest a combined shunt).



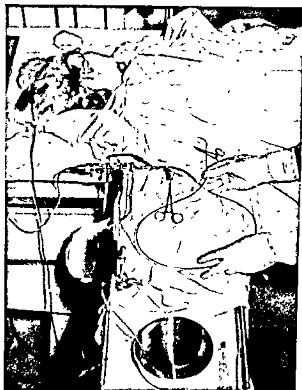


Fig. 3. Photographs of cardiac catheterization laboratory showing: above, the fluoroscopy table and electronic recording equipment used in catheterization, and, below left, patient on table with oximeter ear piece in place for estimation of peripheral arterial oxygen saturation. Cardiac catheter attached to strain gauge manometer and Couvette oximeter is ready for insertion in antecubital vein.

methods. The Couvette oximeter is extremely valuable for determination of oxygen saturations since a continuous recording of saturation may be obtained during gradual withdrawal of the catheter from pulmonary artery to vena cava. Thus, the point of the shunt may be determined with a high degree of accuracy.

Pressure measurements and continuous pressure tracings are important in recognizing valvular or infundibular subvalvular stenoses and in demonstrating valvular incompetence. Recent development of technics of left heart catheterization either by direct left atrial puncture or by left ventricular puncture has increased the accuracy in localizing right-to-left shunts by detection of blood of low oxygen saturation on the left side of the heart. Such technics are valuable in demonstrating the effects of congenital aortic or mitral stenosis but are not without potential danger of complications from intrapericardial hemorrhage.

The dye dilution curve is another technic being used in well-equipped diagnostic centers in demonstrating both left-to-right and right-to-left shunts by right heart catheterization. A small volume of Evans blue dye is injected into the chambers of the right heart and a recording is made of the appearance curve of the dye in the peripheral arterial system usually by ear lobe oximetry. Typical appearance curves may be recognized for right-to-left as opposed to left-to-right shunts

Fig. 4. (Continued from preceding page) Angiocardiograms from same patient showing course of radiopaque iodide solution in, above, pulmonary veins and left ventricle and, below, left ventricle and thoracic aorta.

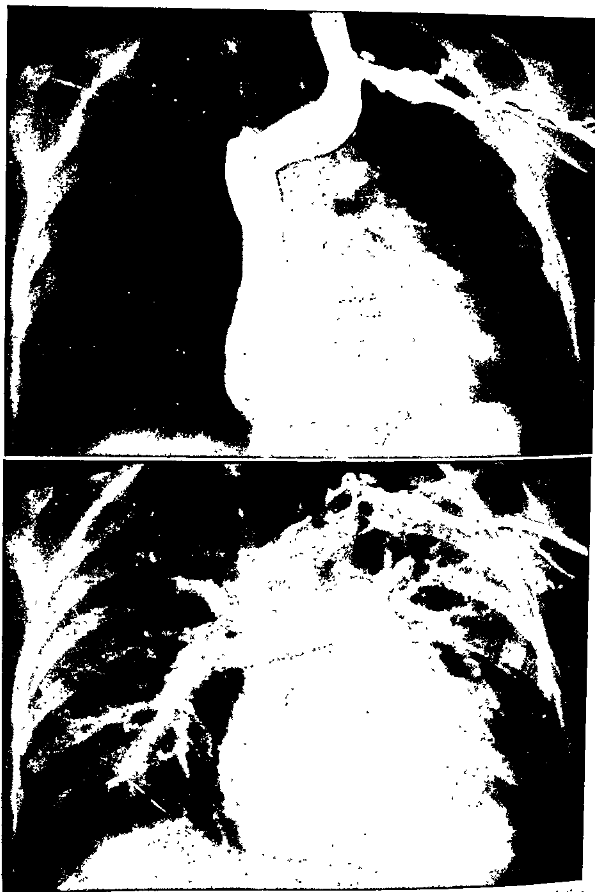


Fig. 4. Angiocardiograms made in normal subject showing course of radiopaque iodide solution through cardiac chambers demonstrating; above, superior vena cava and right atrium and, below, right ventricle and pulmonary arteries.

Fig. 4. (Continued from preceding page) Angiocardiograms from same patient showing course of radiopaque iodide solution in, above, pulmonary veins and left ventricle and, below, left ventricle and thoracic aorta.



Fig. 5. Retrograde aortogram made in newborn infant showing normal aortic arch and thoracic aorta. In this patient, who had congestive heart failure and cardiomegaly, a diagnosis of patent ductus arteriosus was excluded by this study.

Expected Results of Surgical Treatment.

A. Lesions in which surgical methods are recom mended
   1. Good or excellent results
      a. Coarctation of the aorta
      b. Aortic vascular ring
      c. Aortic and subaortic stenosis
      d. Pulmonic valvular or infundibular stenosis
      e. Tetralogy of Fallot
      f. Tricuspid atresia
      g. Pulmonary arteriovenous fistula
      h. Ventricular septal defect
      i. Atrial septal defect
      j. Patent ductus arteriosus
      k. Anomalous drainage of pulmonary veins
      l. Sinus of Valsalva fistula
      m. Aorticopulmonary septal defect
      n. Cor triatriatum
   2. Fair or poor results
      a. Ebstein's disease
      b. Complete transposition of great vessels

B. Lesions in which surgery is not feasible
   a. Eisenmenger complex
   b. Truncus arteriosus
   c. Endocardial fibroelastosis

COARCTATION OF THE AORTA

Coarctation of the aorta is a congenital disease characterized by significant narrowing or complete obstruction of the aortic lumen usually involving the distal segment of the aortic arch but occasionally occurring in the descending thoracic or even the abdominal aorta. Its incidence according to postmortem studies is about 1:1,000 with reported figures ranging from 0.08 to 0.14 per cent. The etiology of the disease remains obscure, although various theories have been proposed to explain its development. Perhaps the most popular of these is the skodiac theory of Craig, which assumes extension of fibrosis into the aorta from faulty ductal closure. Other theories are based on faulty embryonic formation of the arch and "relative stagnation" of aortic arch blood flow during the period of fetal circulation. None of these theories, however, has proved entirely acceptable.

Because of the wide variations in the anatomic forms of coarctation that may be encountered, a number of different classifications have been proposed. Of these the most commonly used is that of Bonnet, who distinguished two types, the "infantile" and the "adult." In the former, the coarcted area lies proximal to the ductus arteriosus with a more diffuse constriction that may involve the aortic isthmus. In the latter, the coarctation lies immediately adjacent or distal to the insertion of the ductus and tends to be well localized. Although a number of other classifications have been proposed, the most satisfactory, according to clinical and surgical considerations, is that which is based upon two significant criteria: (1) the relation of the coarctation to the ductus arteriosus, i.e., preductile or postductile, and (2) the question of whether the ductus arteriosus is patent (Fig. 6). Coarctation of the aorta is associated with a patent ductus arteriosus in about 10 per cent of cases. In such instances, if the ductus is located proximal to

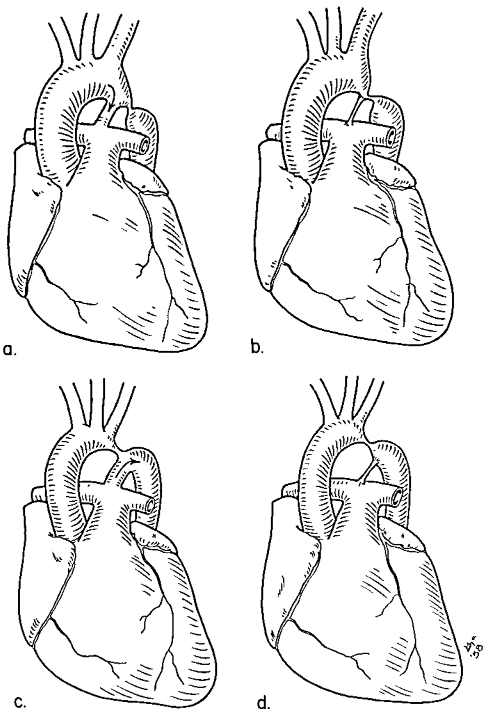


Fig. 6. Diagrammatic drawings illustrating classification of coarctation of aorta according to relation with the ductus arteriosus. Thus, the coarctation is postductile in a and b and preductile in c and d, and the ductus arteriosus is patent in a and c and closed in b and d.

the coarctation, blood flow is from the aorta to the pulmonary artery and a well-developed collateral circulation must exist at birth to sustain life (Fig. 6a). If the patent ductus is located distal to the coarctation, the direction of blood flow through the ductus is dependent upon the presence or absence of collateral circulation. In the presence of a poorly developed collateral system, blood flows from the pulmonary artery into the distal

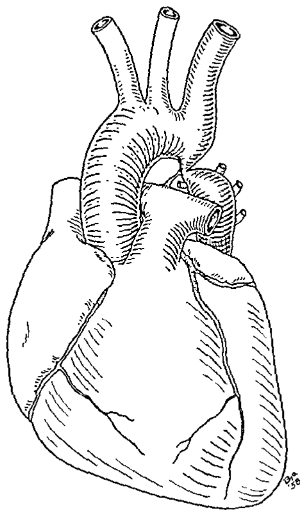


Fig. 7. Drawing illustrating the most commonly encountered clinical form of coarctation of the aorta.

aorta producing cyanosis in the lower half of the body (Fig. 6c). With a well-developed collateral system, blood flows from the aorta into the pulmonary artery.

In most cases encountered clinically, the coarctation is located close to and usually just distal to the aortic insertion of the ligamentum arteriosum (Fig. 7). Occasionally, however, the areas of narrowing may lie more proximally to involve the segment between the left common carotid and the left subclavian arteries. More rarely it may be located in the distal portion of the descending thoracic aorta and may even extend down to involve the upper segment of the abdominal aorta. Although in most cases the coarcted segment is fairly well localized and relatively short, in some the zone of narrowing may extend for a distance of several centimeters (Figs. 8, 9). Proximal to the point of greatest narrowing, the diameter of the aorta tapers gradually towards the stricture and then distally tends to dilate. In some cases this dilatation may assume actual aneurysmal formation. Although there may be complete obstruction of the lumen at the site of greatest narrowing, in most cases an opening measuring a few millimeters in diameter is present. Histologically, the structural changes in the aortic wall are most notable in the coarcted segment and are characterized proximally by medial thickening which tends to project into the lumen and by a fibrous and collagenous intimal proliferation which tends to be indurated and inflexible and poorly attached to the underlying media (Fig. 10). Occasionally, and particularly in older individuals, atheromatous plaques with or without calcification may be present. In the segment of aorta just distal to the stricture, the aortic wall may show focal changes to which the term "jet lesion" has been applied on the basis that they presumably result from the traumatic effects of the jetlike stream flowing through the narrowed lumen. This lesion is characterized by localized fibrous intimal thickening producing a corrugated appearance to the intimal surface with distortion and thinning of the media.

Other congenital anomalies involving the cardiovascular system are associated with coarctation in a significant proportion of cases. The relative incidence of these lesions varies with the type of cases from which the studies are made. Thus, in autopsy material and in patients dying within the first year of life, the incidence and severity of these lesions are high. Among patients surviving to adulthood, patent ductus arteriosus is one of the most common lesions encountered, occurring in about 15 per cent. Another relatively common associated anomaly is aortic valve deformity, particularly bicuspid valve with or without insufficiency or stenosis. Other less common anomalies include interventricular or interatrial septal defects, mitral valve deformity, pulmonary stenosis, and subendocardial fibroelastosis.

The development of collateral circulation in coarctation of the aorta has both physiologic and clinical significance since, from the former standpoint, it is the means by which

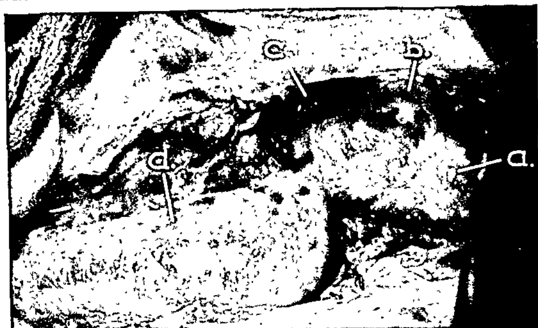


Fig. 8. Photograph made at operation showing characteristic gross appearance of usually encountered clinical form of coarctation; a, dilated left subclavian artery; b, aortic arch; c, ligated stump of obliterated ductus arteriosus; and d, descending thoracic aorta.

Fig. 9. Photograph made at operation showing somewhat elongated coarcted segment; a, left subclavian artery; b, transverse arch of aorta; c, ligated stump of obliterated ductus arteriosus; and d, descending thoracic aorta.

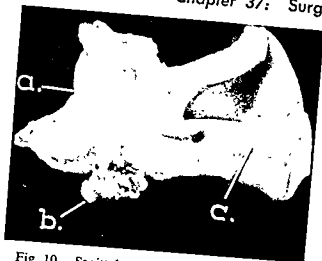


Fig. 10. Sagittal segment of aorta with coarctation removed surgically showing characteristic gross pathologic features of mural thickening and infolding producing luminal narrowing; a, aortic arch; b, ligated end of aortic insertion of obliterated ductus arteriosus; and c, descending thoracic aorta.

obstruction to aortic circulation is overcome and, from the latter, it is of diagnostic value. The major source for these anastomotic channels is derived from the branches of the subclavian arteries, which include principally the thyrocervical trunk, the costocervical trunk, and internal mammary arteries (Fig. 11). Through their branches, including principally the inferior thyroid, superior intercostal, transverse cervical, transverse scapular and subscapular arteries, communications are made with the intercostal arteries, thus providing circulation from the aorta above to that below the level of the coarctation. In addition, the internal mammary artery, through its continuation in the abdominal wall as the superior epigastric artery and the communications of this vessel with the lumbar arteries and the inferior epigastric artery, provides circulation respectively to the abdominal aorta and the external iliac artery. By virtue of their function, these communicating arterial pathways become greatly dilated and tortuous and may produce conspicuous pulsations. Accordingly, the presence of these pulsations, which are readily palpable and often visible, especially about the shoulder girdle, in the axilla, or below the scapulas, provides a valuable diagnostic sign. As a consequence of this factor, too, the tortuous loops of the intercostal arteries gradually produce focal erosion of the lower margin of the ribs resulting in the characteristic notching observed in roentgenograms of the chest.

Clinical Manifestations. The clinical manifestations of coarctation are fairly characteristic, although symptoms, particularly early in life, may be minimal or absent. Indeed, in some patients, the condition may go unnoticed throughout childhood and early adult life during which growth and physical development may be quite normal. In many patients, symptoms may first appear after some excessive physical activity or intercurrent infection. The most common subjective manifestations include headaches, vertigo and dizziness, dyspnea, palpitation, increased fatigability, and epistaxis. Less frequently, the patients may complain of flushing and throbbing in the eyes, peculiar sensations in the head, pain in the trunk and arms, and occasionally of angina pectoris and intermittent claudication in the lower extremities.

On physical examination, the most characteristic findings are high blood pressure in the upper extremities and absent or low blood pressure in the lower extremities, palpable pulsations in the arteries over the back or front of the chest and particularly about the scapular or interscapular regions, excessive arterial pulsations at the root of the neck, and a systolic murmur heard best over the base of the heart and often transmitted to the interscapular region of the back. In most patients, there is moderate to severe elevation of systolic and to some extent of diastolic pressures in the upper extremities, but in some patients, particularly children and less frequently young adults, these pressures may be within a normal range or only slightly elevated. Under the latter circumstances the relative values obtained for the blood pressure in the upper and lower extremities are particularly significant. In normal individuals, the blood pressure in the legs is slightly higher than that in the arms, whereas in coarctation these values are characteristically reversed, and even in the presence of relatively normal pressures in the arms the pressure in the legs will be found well below that in the arms and is often unobtainable by the cuff sphygmomanometer. In this connection, the palpatory findings of arterial pulsations may be highly significant. In normal subjects,

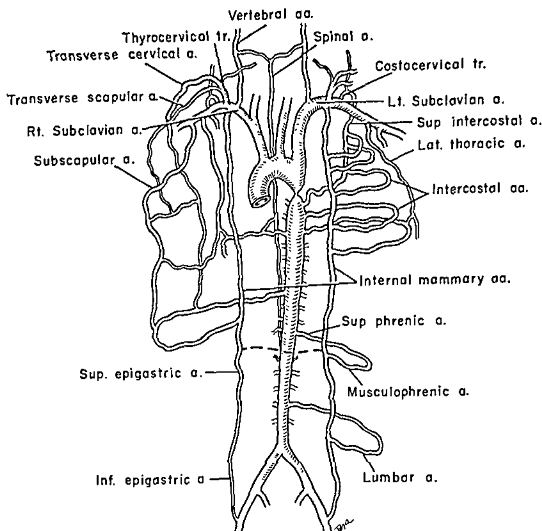


Fig. 11. Diagrammatic drawing showing collateral circulation in coarctation of the aorta.

for example, the femoral and pedal pulses, the dorsalis pedis and posterior tibial, are readily palpable, whereas in coarctation they are either greatly diminished or absent. On the other hand, arterial pulsations, which are normally not present in the chest and back, may be readily palpated in the presence of coarctation. They are usually found on the posterior wall of the chest just below and medial to the lower edges of the scapulas, along the anterolateral aspect of the chest, in intercostal spaces just below the breasts, in the axilla and axillary folds, and above and below the clavicles. Occasionally, pulsations may be noticed in the epigastrium and anterior abdominal wall.

Although murmurs are present in most patients with coarctation, they are quite variable both in character and location. The most frequent type of murmur is a precordial systolic bruit of mild to moderate intensity heard best over the base of the heart and transmitted to the interscapular regions usually on the left side. Diastolic murmurs may also occur and have been reported in about 20 per cent of cases. Their presence is particularly significant as they may indicate associated anomalies, such as patent ductus arteriosus, insufficient bicuspid aortic valve, endocarditis, or interseptal defect.

The most important laboratory studies are electrocardiography and roentgenography of the chest. In most cases, and especially in children, the electrocardiogram is normal. In

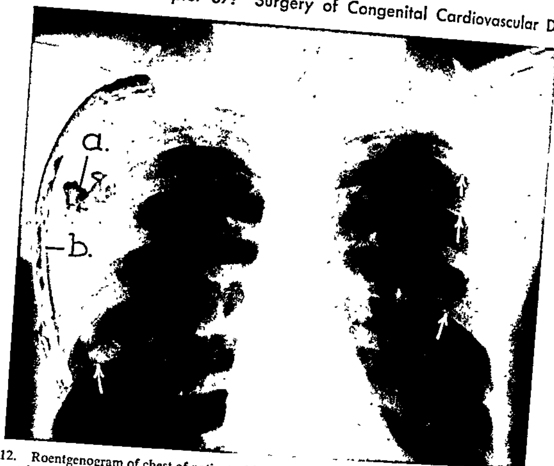


Fig. 12. Roentgenogram of chest of patient with coarctation of aorta treated surgically showing characteristic notching of inferior borders of ribs (indicated by arrows), lack of prominence of aortic knob, and slight left ventricular hypertrophy. a, excised segment of coarctation removed at operation; b, segment of left fifth rib removed at thoracotomy, showing areas of focal erosion along its inferior surface produced by enlarged tortuous intercostal artery resulting in roentgenographic appearance of rib notching.

about one third of the patients, and particularly in those beyond the third decade of life, evidence of left ventricular hypertrophy or strain is present. Its main significance lies in evaluating the status of the heart particularly in regard to associated anomalies and to its tolerance of the hypertension.

On roentgenographic examination of the chest the characteristic manifestations of coarctation are notching or scalloping of the ribs, lack of prominence of the aortic knob, and evidence of left ventricular hypertrophy (Fig. 12). In perhaps about 20 per cent of cases, however, and most frequently in infancy and early childhood, these findings are not demonstrable and little variation from normal may be observed in the chest roentgenogram. Rib notching, which usually appears after the age of 10 years, is the most characteristic finding and may be considered pathognomonic of the disease, although rarely it may be produced by neurologic and vascular lesions of the chest wall, such as neurofibromatosis of the intercostal nerves and arteriovenous fistulas. A significant radiologic sign, in some cases, consists in the presence of a double shadow in the region of the aortic knob, the upper component of which is produced by the dilated left subclavian artery and the lower part by the poststenotic segment of the descending thoracic aorta (Fig. 13). Although in the diagnostic study of most patients with coarctation angiocardiography is not necessary, it may be indicated and can provide useful information under certain unusual circumstances.

Prognosis. The serious nature of coarctation, if untreated, has been well demonstrated by a number of studies. Abbott, for example, found that death occurred before the age of 30 years in about half the patients and before the age of 40 years in about three fourths of the patients. Somewhat similar figures were obtained by Blackford. In the majority of



Fig. 13. Roentgenogram of patient with coarctation of aorta showing significant radiologic sign of double shadow in region of aortic knob: the upper component, a, is produced by dilated left subclavian artery and the lower part, b, by poststenotic segment of descending thoracic aorta. Characteristic rib notching and moderate left ventricular hypertrophy are also shown.

cases, death results from cardiovascular causes, such as heart failure, rupture of the aorta or heart, endocarditis and cerebral lesions. It is thus apparent that the disease is associated with high morbidity and decreased life expectancy, facts that emphasize the need for proper therapy.

Treatment. Surgical removal of the coarcted segment with restoration of aortic continuity by end-to-end anastomosis or by use of an aortic graft constitutes the most effective form of treatment of coarctation (Figs. 14, 15, 16). In general, it is considered preferable to delay operation until the patient is over six years of age. In younger patients, however, operation may be mandatory under certain urgent circumstances, such as heart failure or progressive cardiomegaly.

Results of surgical treatment have been increasingly gratifying. In the majority of cases, symptoms are relieved and the blood pressure in the extremities is restored toward normal levels. In uncomplicated cases operative mortality and morbidity rates are relatively low, being less than 5 per cent.

VASCULAR ANOMALIES PRODUCING TRACHEAL OR ESOPHAGEAL COMPRESSION (VASCULAR RINGS)

Abnormalities in development of the aortic arch system may lead to displacement, constriction, or compression of the trachea and esophagus. Such arterial anomalies in the thorax are common, often complex, and may occur in a number of forms. The most frequent types are the double aortic arch, right aortic arch with left ligamentum arteriosum, anomalous innominate artery, anomalous left common carotid artery, and aberrant subclavian artery.

Principal clinical features of vascular rings are usually related to tracheal or esophageal obstruction. Dysphagia (dysphagia lusoria) may or may not be present but is only produced by vascular rings which produce posterior compression of the esophagus. Disturbed swallowing may be manifested in several ways and may vary according to the type of food taken. For example, fluid may produce difficulties in a patient who swallows

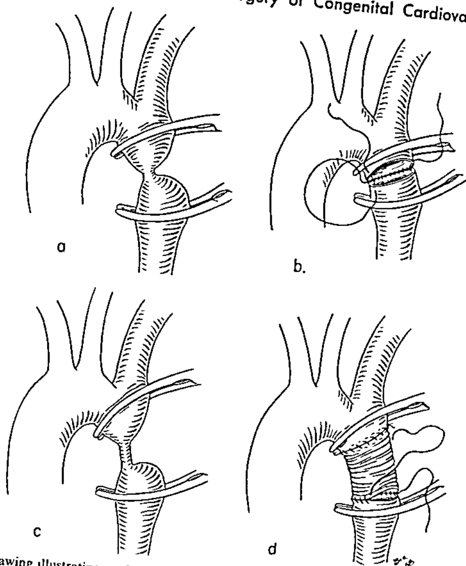


Fig. 14. Drawing illustrating methods of surgical treatment of coarctation of aorta: a, common form of coarctation in which end-to-end anastomosis, b, may be employed; c, longer form of coarcted area requiring use of graft, d, for replacement of excised segment.

semisolids normally. In some patients the reverse may be true. Nursing infants may even have regurgitation of milk and have peculiar gasping action.

Respiratory distress with stridor and inspiratory retraction of intercostal and supraclavicular tissues is characteristic of anterior compression of the trachea. These symptoms are frequently associated with double or bifid aortic arch and appear during infancy. Respiratory rate is usually increased and a noisy "crowing" respiration is audible even without a stethoscope. Respiratory symptoms are aggravated by ingestion of milk. Babies have a natural tendency to hyperextend the neck to obtain a free air passage. Infections of the lower respiratory tract may ensue, sometimes related to aspiration. A resulting bronchopneumonia may complicate an already serious condition. Death in infants is usually the result of respiratory embarrassment.

Roentgenographic examination is the most valuable diagnostic procedure available. Ordinary films may reveal pneumonitis (Fig. 17). Bronchograms show displacement and constriction of the lower trachea (Fig. 18). Lipiodol or barium esophogram may show posterior indentation of the esophagus at the same level. The combination of posterior encroachment upon the trachea and anterior constriction of the trachea are findings which for practical purposes are diagnostic of a vascular ring.

Fig. 15. Photograph made at operation following completion of procedure of end-to-end anastomosis after resecting coarctation of aorta as shown in Figure 8.

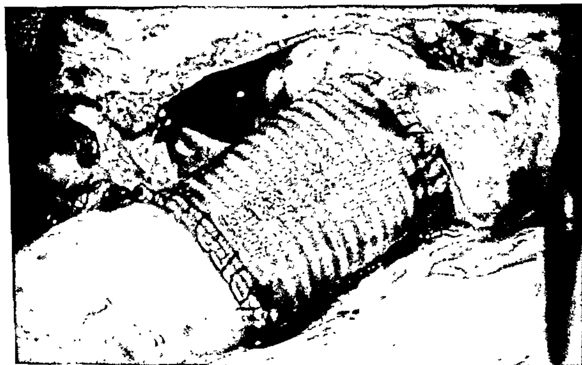


Fig. 16. Photograph made at operation showing completed procedure of graft replacement after resection of coarctation of aorta shown in Figure 9.

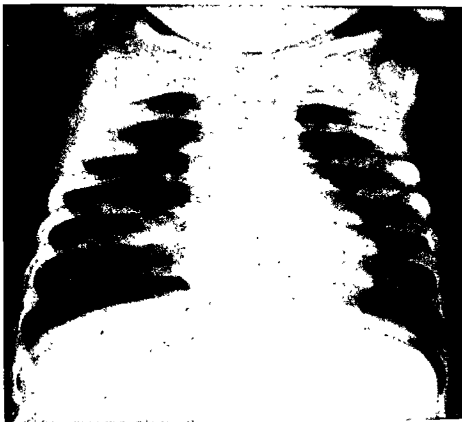


Fig. 17. Roentgenogram of chest in eight-month-old infant with double aortic arch showing aspiration pneumonia of right middle lobe.

Surgical Treatment. Only those anomalies producing symptoms or evidence of impairment of tracheal or esophageal function deserve operative intervention. Largely because of the efforts of Gross, the technic of operation upon aortic arch anomalies has been greatly improved. The purpose of operation in every case is relief of tracheal and esophageal obstruction without sacrifice of major vital blood vessels. Although in some instances it is practical to divide an anomalous subclavian artery without restoration of circulatory continuity, carotid circulation should never be permanently interrupted (Fig. 19). In instances of double aortic arch, the arch which is present on the left side of the trachea is fortunately often the lesser of the two and division may be safely performed (Fig. 20). Under these circumstances, the left arch may be divided between the origins of the left common carotid artery and the left subclavian artery (Fig. 20). In some cases, a ligamentum arteriosum enters into the formation of the aortic arch and must be divided as part of the repair. A simple, uncomplicated retroesophageal right subclavian artery originating from a normal left descending thoracic aorta does not require surgical interruption. If symptoms (dysphagia lusoria) are present, the vessel should be divided.

CONGENITAL AORTIC AND SUBAORTIC STENOSIS

Stenosis of the aortic valve, like stenosis of the pulmonary valve, may involve the valve leaflets and commissures or may occur in a subvalvular position. In the latter instance, the lesion is referred to as subaortic stenosis and is usually a fibromuscular ridge or membrane in the left ventricular outflow tract. Whereas subaortic stenosis is always a congenital abnormality, valvular aortic stenosis may be either congenital or acquired.

In most instances, the symptoms during childhood are minimal, but if the stenosis is extreme, the patient may suffer from cerebral ischemia manifested by spells of syncope, sometimes accompanied by convulsions and sudden death. In newborn infants, a severe

Fig. 18. Bronchograms and esophagrams in patient in Figure 17 showing tracheal and esophageal constriction produced by aortic vascular ring. Patient had severe respiratory stridor and regurgitation of food.

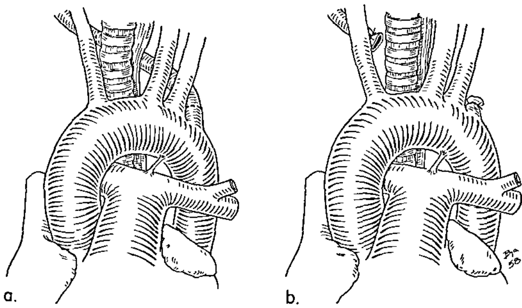


Fig. 19. Drawing showing retroesophageal right subclavian artery, which takes origin from descending thoracic aorta. Division of the artery relieves esophageal compression.

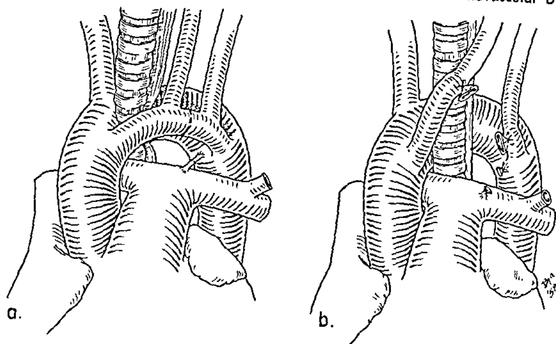


Fig. 20. Drawing showing complete vascular ring produced by bifid aorta. Relief of tracheal and esophageal obstruction is obtained by interruption of the lesser arch to left of trachea and release of the ring.

stenosis leads to pulmonary edema and dyspnea, and pulse pressure may be so reduced that peripheral pulses are not palpable.

Characteristic physical findings include the presence of cardiac enlargement and a harsh thrill and systolic murmur to the right of the sternum. Aortic closing sound may be present but is not loud. The murmur is transmitted readily to the suprasternal notch and may be audible in the axillary and brachial arteries. Pulse pressure is usually reduced unless some aortic incompetence is also present.

Aortic valvulotomy should be done for patients who have syncopal attacks or findings of left ventricular strain on electrocardiogram and progressive cardiac enlargement. Occasionally in small infants operation must be done as an emergency. At present the most widely accepted method of valvulotomy or subaortic resection is a transventricular approach to the valve using cardiac inflow occlusion and hypothermia or temporary cardiopulmonary bypass. Results of operation are generally satisfactory although mild aortic regurgitation may follow an extensive valvular dissection.

PULMONIC STENOSIS

Isolated or pure pulmonic stenosis with intact ventricular septum is a lesion in which obstruction to right ventricular outflow is the predominant physiologic disturbance. Two types of pulmonic obstruction are recognized, and both may be present in the same patient. In the commoner type, stenosis of the pulmonary valve is present and the valve is fused into a conical shape with a perforation at the apex (Fig. 21). In a much less frequent type, the obstruction occurs in a subvalvular position involving the infundibulum or conus region of the right ventricle (Fig. 22). In this position, a fibromuscular ring is located in the outflow tract of the ventricle, usually at the level of hypertrophied crista supraventricularis. A number of anatomic variations may occur, depending upon the level at which the infundibular obstruction is located. An infundibular chamber or so-called third ventricle may be produced in instances where the infundibular stenosis is several centimeters below the valve.

Cyanosis is typically absent in this defect, but perhaps in fewer than 50 per cent of cases a small septal defect is present, usually in the interatrial septum. If the pulmonary stenosis is severe, a right-to-left shunt occurs, producing cyanosis. Not uncommonly, therefore, even a slitlike patency of the foramen ovale may produce a significant right-to-left shunt and cyanosis. In this lesion, right ventricular

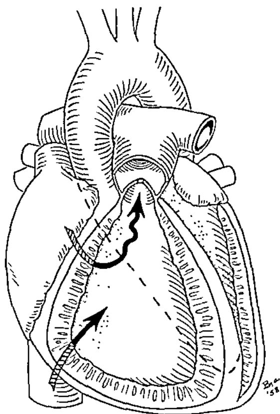


Fig. 21. Diagram showing isolated stenosis of pulmonary valve with intact ventricular septum. Poststenotic dilatation of the pulmonary artery is a characteristic finding in this anomaly.

strain and right sided failure are characteristic. Clinical findings usually include dyspnea on exertion which may be intense. Spells of paroxysmal dyspnea during infancy are frequent, and death may occur suddenly during such an episode. Syncopal attacks are not uncommon in older children. Cyanosis may or may not be present, depending upon the presence of an intracardiac shunt, but usually the cyanosis is not severe or accompanied by clubbing of the nails. So-called "peripheral" cyanosis may be evident indicating a reduced cardiac output and sluggish capillary flow. Squatting after exertion, which is common in patients with tetralogy of Fallot, is not typical in isolated pulmonic stenosis.

The characteristic physical finding is a harsh systolic murmur often accompanied by a palpable thrill along the left sternal border in the third intercostal space. The murmur is transmitted upward toward the left clavicle and no pulmonic second sound is audible. A substernal heaving pulsation signifies the presence of right ventricular hypertrophy. Extreme cardiac enlargement and hepatomegaly usually indicate the presence of secondary cardiac failure.

Roentgenograms reveal right ventricular enlargement. Dilatation of the main pulmonary artery segment is produced by hemodynamic factors produced by the turbulence in the blood stream distal to the stenotic valve (Fig. 23). This finding is useful in differentiating isolated pulmonary stenosis from tetralogy of Fallot and other defects in which the pulmonary artery is usually smaller than normal. Angiocardiography may be useful to demonstrate the anatomy of the outflow tract and in differentiating a valvular from infundibular stenosis.

Electrocardiograms show right ventricular preponderance, and in severely ill children or infants a strain pattern is present.

Cardiac catheterization is extremely useful and reveals an elevated right ventricular pressure often exceeding 200/0 mm. Hg. If an infundibular chamber is present, accompanied by both infundibular and valvular stenoses, an intermediate pressure zone may be detected in the outflow tract. In this chamber, a pressure lower than the pressure in the main chamber of the right ventricle is demonstrable and the pressure in the pulmonary artery is even lower, being 10 to 20/0 mm. Hg.

Prognosis in this lesion depends upon the pressure in the right ventricle. Right ventricular pressures less than 70 mm. Hg systolic are usually well tolerated. If the right ventricular pressure exceeds 80 to 100 mm. Hg, however, surgical treatment is indicated. In infants manifesting severe right ventricular failure, pulmonary valvulotomy must be done as an emergency procedure.

The first successful surgical attempts at pulmonary valvulotomy were made by Brock and Sellers of London, and the technic is often referred to as the "Brock Operation." In this procedure valvulotomes and dilators are passed through the right ventricular wall to incise and dilate the stenotic valve. A guillotine type valvulotome has more recently been used with better results than the instruments originally devised. Relief of symptoms

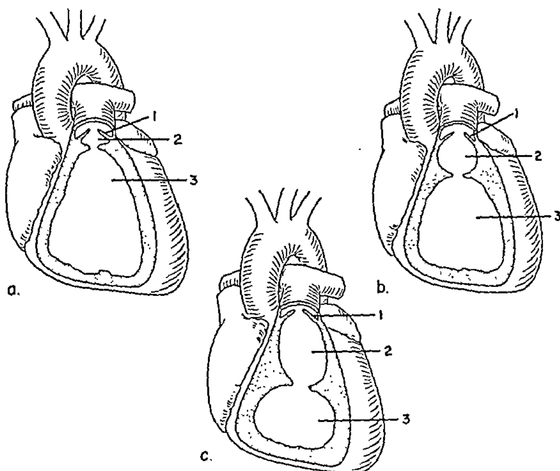


Fig. 22. *Diagrams showing types of subvalvular or infundibular pulmonic stenosis. The numbers 1, 2, and 3 identify the pulmonic valve, infundibular chamber, and right ventricular chamber. The infundibular chambers vary in size depending upon proximity of infundibular stenosis to pulmonic valve.*

is expected if the obstruction to right ventricular outflow is relieved.

During the past ten years numerous modifications of pulmonary valvulotomy and infundibular resection have been made. The most important were the application of open technics employing general body hypothermia or the pump oxygenator for temporary cardiopulmonary bypass. The latter is particularly useful if an infundibular stenosis or significant atrial or ventricular septal defect is present. In these cases, the pump oxygenator provides a means of total correction of the defect or defects with acceptable low risk.

TETRALOGY OF FALLOT

The combination of pulmonary stenosis, ventricular septal defect, and dextroposition of the aortic root produces a right-to-left shunt and a cyanotic state known as tetralogy of Fallot. This lesion assumes great importance, since it is the commonest type of "blue baby." The pathologic anatomy of this complex was first described by Peacock in 1866; later a detailed report of a series of cases by Fallot in 1888 clarified the syndrome which now bears his name.

Although in the past some disagreement existed regarding the criteria necessary for making this diagnosis, for the sake of uniformity only those patients with dextroposition or overriding of the aorta in combination with a ventricular defect and pulmonary stenosis or atresia should be included in this diagnosis (Fig. 24). The venous blood in tetralogy reaches the right ventricle and meets the obstruction in the outflow tract. The unoxygenated blood is shunted readily into the dextroposed aorta through the ventricular defect producing the cyanotic state. Usually these patients have no evidence of right ventricular strain or right sided failure. The right ventricle tends to hypertrophy under the



Fig. 23. Roentgenogram of chest in patient with isolated valvular pulmonic stenosis showing characteristic dilatation of main pulmonary artery.

strain of contraction against systemic pressure. The left atrium and ventricle receive a reduced quantity of blood and are usually underdeveloped. Intracavitary pressure in the right ventricle usually does not exceed aortic pressure since this ventricle has ready access to the aorta, which overrides the ventricular septum receiving part of the right ventricular output, the remainder entering the pulmonary artery, depending upon the degree of pulmonic stenosis present. Pulmonary circulation is greatly reduced and collateral vessels, provided predominantly by the bronchial arteries, may contribute significantly to pulmonary flow. The pulmonary stenosis usually involves the pulmonary artery and also the valve and the infundibulum of the right ventricle.

In this malformation, the outstanding features are intense cyanosis and clubbing of the extremities combined with a heart of normal size. The intensity of the cyanosis is highly variable, depending mostly upon the severity of pulmonary stenosis and the extent of dextroposition of the aorta. In severely incapacitated patients dyspnea is present even at rest, but in less severe lesions dyspnea and cyanosis are evident only following exertion.

Dyspnea usually limits the activities of the patient since not uncommonly an arterial oxygen saturation of 85 per cent at rest falls to 40 to 50 per cent with mild exertion. Squatting with fatigue is a typical habit among patients with tetralogy of Fallot. After extreme exhaustion, infant patients often assume the knee-chest position. Attacks of paroxysmal dyspnea are common in infants,

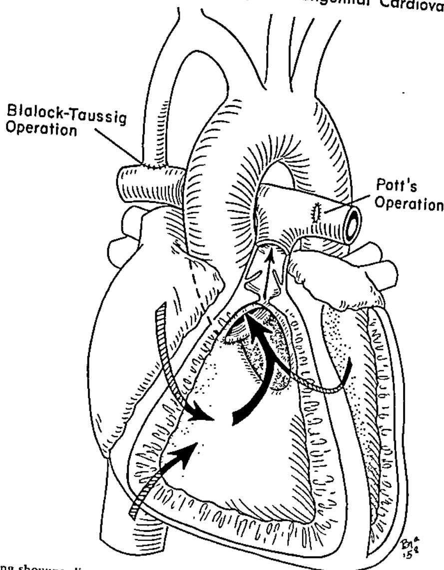


Fig. 24. Drawing showing diagrammatically the defects typical of tetralogy of Fallot which lead to a right-to-left intracardiac shunt and consequent pulmonary ischemia. Systemic pulmonary arterial anastomoses of Blalock-Taussig and Potts for relief of cyanosis are shown.

and such spells may be erroneously diagnosed as epilepsy since loss of consciousness and convulsions may occur.

The most significant and consistent laboratory finding is polycythemia. Red blood cell count may exceed 10 million and hematocrit may be 80 per cent or more.

Stunting of growth is common and many patients more than two years of age are undernourished. Onset of puberty is usually delayed.

Physical findings reveal striking cyanosis with plum colored mucous membranes and clubbed nails (Fig. 25). The heart is usually small or normal in size, although the enlarged right ventricle may produce convexity of the overlying chest wall. Heart action is usually forceful and a systolic murmur is heard to the left of the sternum. Intensity of this murmur depends upon the degree of pulmonic stenosis. In instances of severe pulmonary atresia, no pulmonic murmur is audible. Pulmonary second sound is reduced or absent. The aortic second sound, however, is usually louder than normal, and since the aortic root is large, the aortic sound may be confused with the pulmonic second sound.

Roentgenographic findings usually include a small heart, right ventricular hypertrophy, concave pulmonary conus, and decreased pulmonary vascularity. A right aortic arch occurs in more than 15 per cent of cases.



Fig. 25. Severe clubbing of fingernails and toenails in cyanotic boy aged 14 years with tetralogy of Fallot.

Fluoroscopy with barium filled esophagus is useful to delineate the course of the aortic arch. Angiocardiography reveals simultaneous filling of the aorta and pulmonary arteries confirming the presence of overriding aorta (Fig. 26). Cardiac catheterization shows increased right ventricular pressure which does not exceed systemic arterial pressure, and if the pulmonary artery can be entered, the pressure is low. Prognosis in tetralogy is fair and perhaps better than for most cyanotic conditions. Whereas most



Fig 26. Angiocardiogram in patient with tetralogy of Fallot showing simultaneous visualization of aortic arch and pulmonary arteries. Severe right-to-left shunt was produced by overriding aorta, ventricular septal defect, and pulmonary stenosis.

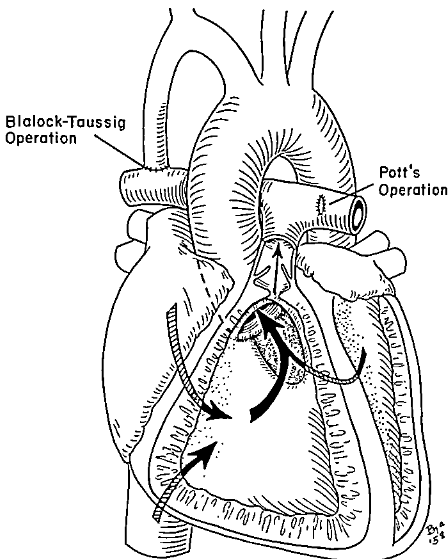


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Creation of a systemic to pulmonary shunt of the Blalock or Potts type increases pulmonary flow and relieves the cyanosis. Resort to surgical treatment is indicated whenever cyanosis is severe or incapacitating. Although results of anastomotic procedures are not as satisfactory as in tetralogy of Fallot, creation of an artificial ductus should be attempted in view of the poor prognosis of the anomaly if untreated. Direct surgical repair of the lesions in tricuspid atresia is not anatomically feasible.

PULMONARY ARTERIOVENOUS FISTULA

Among the rarer causes of cyanosis is pulmonary arteriovenous fistula. This lesion is considered by most to be congenital in origin and has definite hereditary characteristics. The pulmonary lesion may be only one manifestation of a hereditary hemorrhagic telangiectasia, the so-called Osler-Weber-Rendu disease. In more than 50 per cent of cases, the aneurysms are multiple in one or both lungs.

The lesions range from near microscopic size to several centimeters in diameter. Lesions tend to lie subpleurally, and pleural adhesions overlying the distended sac may develop. Disruption of adhesions by coughing or straining may produce bleeding and spontaneous hemothorax (Fig. 27). The fistulous communication usually involves more than one segmental artery and vein. The vessels are dilated and tortuous with aneurysmal dilatations adjacent to the fistulous communication.

The essential findings are cyanosis and clubbing of nails in the presence of a normal heart. Cyanosis appears at a later age than is customary with cyanotic types of congenital heart disease. Dyspnea is usually mild. Bleeding from the nose and pharynx is common and hemoptysis may be severe. Central nervous system involvement may occur because of paradoxical embolism or air embolism. Hemangiomata or telangiectases may be located elsewhere on the body indicating the generalized tendency of the disease process.

A soft, humming, continuous murmur may be audible over the involved pulmonary segment. Cardiac murmurs are absent and cardiac enlargement usually does not occur although multiple fistulas producing a large volume right-to-left shunt are present. Electrocardiogram shows no significant deviation from normal.

Roentgenographically, the arteriovenous fistula or aneurysm may be demonstrated as a cluster of tortuous vessels or well-defined aneurysm sac. Multiple fistulas may be noted. In some instances, the lungs are diffusely studded by multiple minute telangiectases. Angiocardiography may be the only means of demonstrating the lesions, particularly the minute, widely scattered hemangiomatous type.

Surgical resection of the involved segment or lobe may be justified in localized lesions of significant size producing cyanosis and polycythemia. Usually, however, total pneumonectomy should be avoided, since involvement of the remaining lung may be present and the lesions may be aggravated by the excessive resection. Simple ligation of a segmental pulmonary artery or vein is never curative because of the multiple communications present in each aneurysmal sac regardless of size of the lesion.

VENTRICULAR SEPTAL DEFECTS

Defects of the interventricular septum are perhaps the most common true congenital cardiac lesions occurring as isolated anomalies or in combination with valvular and other great vessel malformations. As an isolated anomaly the ventricular septal defect produces characteristic physiologic disturbance. Since pressure in the left ventricle is normally about four times that in the right, a significant left-to-right intracardiac shunt is produced depending upon the size and location of the defect and the resistance to flow in pulmonary arterioles and capillaries. Contrary to previous medical opinion, prognosis in ventricular defects is usually poor and estimates indicate that approximately 70 per cent of patients die of complications of congestive failure during the first year of life. In some patients, however, the defect causes little disability and is compatible with a relatively normal life. In still others, significant retardation of growth and development is noted. Obviously certain factors are respon-

other malformations causing cyanosis are incompatible with life for more than a few months, occasional patients with tetralogy of Fallot may live to adulthood. Of course, wide variation exists depending upon the severity of pulmonary stenosis and overriding of the aorta. Indeed, many infants expire from the effects of pulmonary ischemia and anoxemia before compensatory changes occur which would provide collateral pulmonary circulation.

Surgical treatment for tetralogy of Fallot was introduced in 1944 by Blalock and Taussig—an event which stirred the present enthusiasm for surgery of congenital heart disease. Recognizing the fact that infants with tetralogy not infrequently do well for the first few weeks of life while the ductus arteriosus is normally patent and deteriorate as the ductus spontaneously closes, these observers planned creation of an artificial patent ductus arteriosus. The principle of the Blalock-Taussig "blue-baby" operation is therefore based upon creation of an artificial ductus arteriosus which will permanently provide blood to the pulmonary circulation. In this procedure, a subclavian artery is divided and anastomosed end to side into the pulmonary artery (Fig. 24). Presence of a machinery type continuous murmur after operation is indicative of a satisfactory result. Several years after the Blalock-Taussig operation was devised, Potts introduced a technical modification of this procedure and anastomosed the side of the pulmonary artery to the side of the aorta, somewhat simplifying the operation (Fig. 24).

Brock in 1949 recommended a direct operative attack upon the pulmonary stenosis or infundibular obstruction. Enthusiasm for this procedure has waned, particularly with the recent advent of technics for open heart surgery.

Lillehei and co-workers now advocate total correction of the defects of tetralogy using a pump oxygenator for cardiopulmonary bypass. Repair of the ventricular septal defect and resection of the obstructing elements in the right ventricular outflow tract is performed using polyvinyl or synthetic prostheses if necessary to provide a complete plastic repair in the outflow tracts of right and left ventricles. At present, it is not possible to compare the results of total corrective operations with anastomotic procedures. In general, it may be stated, however, that anastomotic procedures of Blalock-Taussig or Potts are still indicated for infants and for patients with intense cyanosis and extreme aortic overriding. In other patients, complete repair of the defects is the procedure of choice.

TRICUSPID ATRESIA

In this anomaly, no communication exists between the right atrium and right ventricle. The foramen ovale must be widely patent or a gross atrial septal defect must be present in order for this anomaly to be compatible with life. If only a foramen ovale is present, the high pressure in the right atrium holds the foramen open. Usually in patients surviving infancy, a communication exists between the left ventricle and a diminutive right ventricle. Pulmonary stenosis with a narrow pulmonary arterial trunk is common with this defect and the combination of pulmonary ischemia and right-to-left vascular shunt at the atrial level produces a cyanotic state. The small size of the right ventricle in the presence of cyanosis provides the clue to diagnosis and differentiation from other cyanotic conditions.

Clinically, these patients are intensely cyanotic. Frequently, infants will become distressingly anoxemic as the ductus closes spontaneously and death may ensue if emergency measures and surgical treatment are not available. Murmurs may or may not be present, depending usually upon the patency of a ductus arteriosus. The quality of the second cardiac sound is usually single, since only the sound of closure of the enlarged aortic valve is audible.

Roentgenographically and fluoroscopically, an absence of the right ventricle and pulmonary conus distinguishes this from other cyanotic lesions which are associated with pulmonary ischemia.

The electrocardiogram shows left axis deviation, a finding in cyanotic patients which is always suggestive of tricuspid atresia and underdevelopment of the right ventricle. In small infants, however, the electrocardiogram may present a balanced axis.

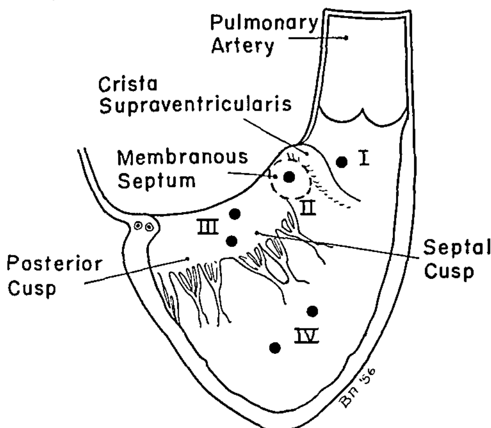


Fig 28. Diagram showing location of defects of the ventricular septum as viewed from the right ventricle. Approximately 85 per cent are in the membranous septum (Type II).

sible for this discrepancy. In the well-known *maladie de Roger*, for instance, in which the defect is relatively small and frequently located in the muscular portion of the septum, a harsh murmur is present, but the effects upon the cardiac function are mild and most patients are asymptomatic. In the past, this observation has led many to consider ventricular defect a relatively innocuous condition from the patient's standpoint. In general, large defects of the ventricular septum either of the membranous or muscular portion have a serious prognosis and surgical correction is necessary whenever it is clinically feasible.

Location of defects in the ventricular septum is important in the problems of diagnosis and treatment. The ventricular septum is composed of a small membranous portion and larger muscular portion. In addition, there is an inflow and outflow area separated by a crista supraventricularis (Fig. 28). Approximately 85 per cent of ventricular septal defects occur in the membranous septum. In this location, cardiac contraction has little tendency to close the defect during systole in contrast to those defects completely surrounded by myocardial tissue. Thus, the membranous defects, particularly those of large size, are associated with the largest volume of shunt and the poorest prognosis.

The murmur of ventricular septal defects may vary from a harsh systolic murmur of *maladie de Roger* to none at all. When the murmur is loud, it is located in the left third or fourth intercostal space and is frequently associated with a palpable thrill. Cyanosis is typically absent, but if pulmonary hypertension results and pulmonary vascular resistance is increased by hypertrophic and proliferative changes in pulmonary arterioles, cyanosis may subsequently appear, due to reversal of the shunt. The pulmonary valve closing sound is almost always accentuated, depending upon pulmonary arterial pressure. Pulse pressure is usually increased, especially in infants, before pulmonary hypertension

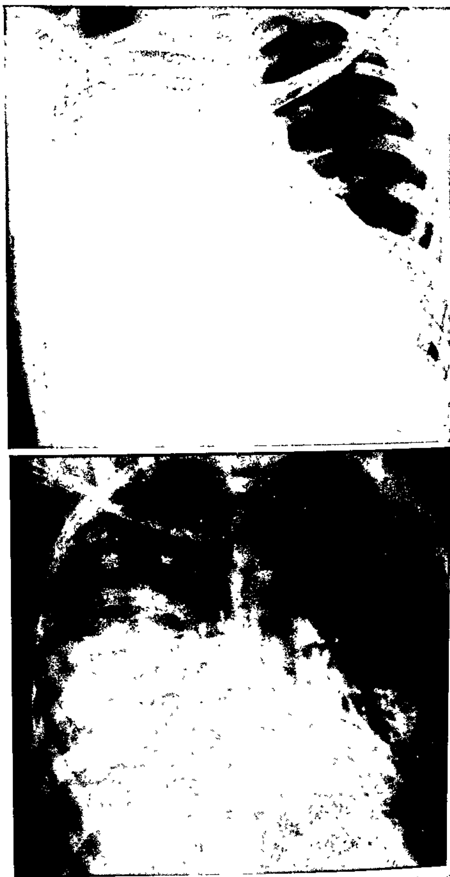


Fig. 27. Above, roentgenogram of chest in 24-year-old patient with spontaneous hemothorax. Below, diagnosis of pulmonary arteriovenous fistula was made by angiocardiography. Patient recovered from illness after decortication of lung and resection of right lower lobe. Note additional small pulmonary arteriovenous fistula in right upper lobe.

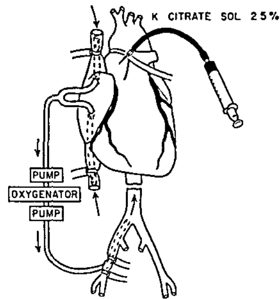
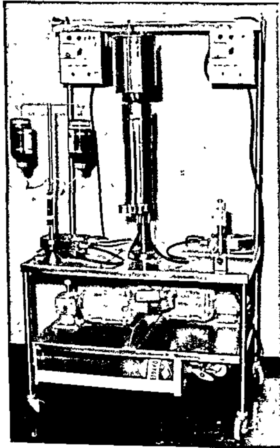


Fig. 30. Scheme of operation using a pump oxygenator for temporary cardiopulmonary bypass. Induced cardiac arrest using potassium citrate solution may be used to facilitate the repair.

present, indicating the presence of a right-to-left shunt. Such cases are usually unsuitable for attempted surgical correction.

Surgical Treatment. Recently methods of surgical correction of ventricular septal defects have been perfected which provide means of obtaining complete cure of the lesion. Development of the pump oxygenator as a *temporary cardiopulmonary* substitute has provided a satisfactory means of exposing ventricular defects for repair under direct vision (Figs. 30, 31). This significant development was the result of efforts by Gibbon, Dennis, Lillehei, Kirklin, and many others.

Patients selected for operation should have a significant left-to-right intracardiac shunt as manifested by left ventricular hypertrophy, cardiac enlargement, and increased pulmonary vascular markings. Optimum age for operation is between two and twelve years, although occasionally operation in small infants is required on an emergency basis. Op-



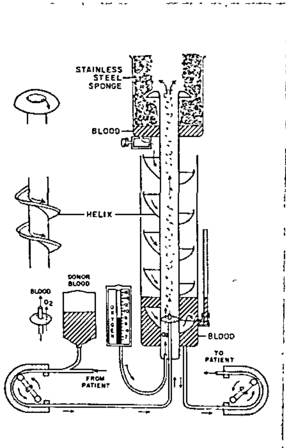


Fig. 31. Photograph and diagram showing pump oxygenator system which utilizes roller pumps and stainless steel oxygenator.



Fig. 29. Roentgenogram of chest in seven-year-old patient with ventricular septal defect showing cardiac enlargement and prominence of pulmonary vascular markings.

develops. Progressive cardiac enlargement is an early warning sign in the asymptomatic patient that cardiac failure is impending. If pulmonary hypertension is extreme, a Graham Steell diastolic murmur of pulmonary valvular incompetence may be audible.

Roentgenograms of the chest show left ventricular enlargement, a prominent pulmonary conus, increased pulmonary vascular markings, and frequently left atrial enlargement (Fig. 29). Fluoroscopy is useful to demonstrate the increased pulmonary flow. In small infants, differentiation between a large patent ductus arteriosus and ventricular septal defect may be made by retrograde aortography (Fig. 5). An injection of 6–10 ml. of 30 per cent Diodrast in the left brachial artery permits visualization of the entire aortic arch. If the contrast medium is visible in the pulmonary vessels, the presence of a ductus arteriosus is confirmed but the possibility of a ventricular defect is not necessarily excluded.

The electrocardiogram reveals left ventricular hypertrophy. If pulmonary hypertension develops, right ventricular hypertrophy occurs. Frequently combined left and right ventricular hypertrophy is demonstrated by electrocardiogram.

In the typical case, cardiac catheterization reveals oxygenated blood in the right ventricle and unmixed venous blood in the right atrium; the pressure in the right ventricle and pulmonary artery is usually elevated but with a small defect may be normal. When the pulmonary and systemic arterial pressures are roughly equal and the oxygen saturation of right ventricular blood only slightly exceeds right atrial saturation, peripheral arterial oxygen unsaturation may be

encountered congenital cardiac defects of young adults. During fetal life, defects of the interatrial septum cause no physiologic disturbance; the blood is directed from right to left in the normal manner. After birth, however, when left atrial pressure exceeds the pressure in the right atrium, the flow reverses. A left-to-right shunt produces a pulmonary flow greater than systemic and consequently an increased burden upon the right ventricle.

Under ordinary circumstances, there is no cyanosis. Mottling of the skin is a frequent finding in young children particularly and may be confused with true cyanosis, but this may be differentiated by the normal color of lips and nail beds. The so-called gracile habitus or thin, weak, small-boned appearance, supposedly characteristic of patients with atrial defects, is by no means constant. The patient with a large incapacitating defect may have a normal growth pattern.

The thorax over the precordium may be deformed, the prominence being due primarily to a dilated and hypertrophied right ventricle. A systolic murmur is usually audible along the left sternal border and is produced in the outflow tract of the hypertrophied ventricle or in the dilated pulmonary artery. The defect itself produces no murmur unless it is associated with an anomaly in the mitral or tricuspid valves. At birth, a murmur is usually absent, and even when it becomes audible, considerable variation may be noted in its location and intensity. The pulmonary valve closing sound is accentuated, and in the presence of right bundle branch block, the sound is widely split.

Roentgenographically cardiac enlargement, principally right ventricular, is evident with prominence of the pulmonary conus and pulmonary vascular shadows. In large atrial defects fluoroscopy may reveal the so-called "hilar dance" produced by the pulsating pulmonary arteries. Electrocardiography indicates right ventricular hypertrophy and often right bundle branch block.

Cardiac catheterization reveals the presence of oxygenated blood in the right atrium. In infants and children pulmonary arterial pressure is often normal, but in the adult the pressure increases and may subsequently equal systemic arterial pressure.

With increasing age right ventricular hypertrophy advances and many patients develop severe pulmonary hypertension. Although this defect may be compatible with a relatively normal infancy and childhood, frequently during early adulthood incapacitating symptoms appear. In general, therefore, cases should be selected for surgery at an early age when cardiac reserve is greater and risk of operation less.

The usual atrial septal defect is located in the upper portion of the septum and represents a failure of the septum secundum to close the ostium secundum or foramen ovale (Fig. 33). If the septum secundum does not develop completely, a true septal defect of clinical significance occurs. In many instances, the septum secundum develops normally, yet a slitlike opening of the foramen ovale persists after birth. Such a lesion may be present throughout life and produce no disturbance in cardiac physiology. Defects located in the lower portion of the atrial septum result from failure in closure of the ostium primum or atrioventricular canal. Because these defects are frequently associated with developmental failures in the embryologic endocardial cushions, a cleft may be present in the mitral or tricuspid valves. An ostium primum defect associated with cleft mitral valve may be associated with mitral regurgitation. Under these conditions left ventricular hypertrophy may be present, adding to the volume of left-to-right atrial shunt and more severe physiologic disturbance. In cases of complete atrioventricularis communis or persistent atrioventricular canal, mitral and tricuspid incompetence may be present as well as interatrial and interventricular shunts. These defects, which are often associated with mongolism, lead to early congestive failure and death during infancy or the first few years of life.

Operation for atrial defect should be recommended whenever manifestations of cardiac enlargement, failure in physical development, or increasing pulmonary hypertension become evident. With recent development of effective and safe methods of surgical closure, procrastination in submitting such patients to diagnostic study and operation is no longer justified.

Surgical Treatment. Selection of patients with atrial septal defect for operation is based

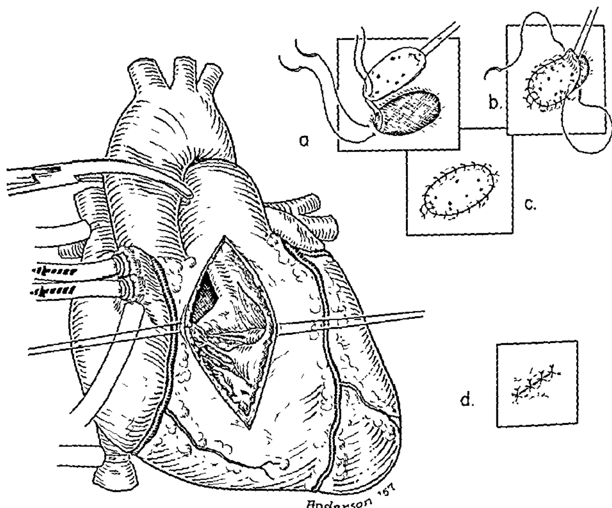


Fig. 32. Drawing showing technic of repair of membranous ventricular septal defect using temporary cardiopulmonary bypass. The defect may be repaired using a patch of synthetic material or by a direct suture technic.

eration should not be advised in the presence of a significant right-to-left shunt through a ventricular defect, of clubbing of nails with severe cyanosis, or of right ventricular hypertrophy and a small left ventricle. In such patients, risk of surgery is high and survivors can expect little if any benefit.

During bypass the right ventricle is incised widely to expose the defect (Fig. 32). Complete cardiac standstill induced by potassium citrate solution or acetyl choline injected into the coronary circulation is used by some surgeons to obtain a quiet and bloodless surgical field inside the heart. Others prefer using intermittent occlusion of the ascending aorta to control coronary flow and coronary sinus return during bypass, and results are equally satisfactory. Although small defects may be sutured directly, for larger defects a polyvinyl sponge patch or tampon over the defect insures complete closure without excessive tension on the suture lines. After the ventriculotomy is repaired and air is eliminated from the cardiac chambers, the bypass is discontinued and cardiac action resumes. In some instances, a transatrial approach to the ventricular defect is preferable, and since it preserves right ventricular integrity, postoperative recovery may be easier. After operation, pulmonary arterial and right ventricular pressures are reduced and cardiac enlargement gradually disappears. In properly selected cases, the mortality from operation is approximately 10 per cent and should improve with advances in diagnostic technic and increased experience.

ATRIAL SEPTAL DEFECTS

Defects of the atrial septum are not uncommon and, in fact, are the most frequently

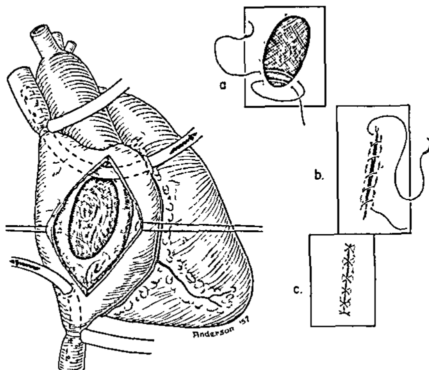


Fig. 34. Drawing showing method of repair of septum secundum type of atrial defect using temporary cardiopulmonary bypass. Direct suture of the defect without use of an occluding patch gives satisfactory results.

tient in an iced tub. At temperatures of approximately 30° C., vena caval return and cardiac inflow interruption are possible for periods of six to eight minutes during which the defect is exposed and repaired. Addition of coronary perfusion during the period of inflow occlusion reduces the danger of cardiac arrhythmia in the cold heart. Because of the limitations on time imposed by this technic and the inability to close ostium primum defects safely, this method also is gradually being discarded by most surgeons.

Cardiopulmonary bypass offers the most satisfactory means of repair for atrial septal defects permitting accurate and satisfactory repair of all types with the possible exception of some extensive types of complete atrioventricularis communis. Defects of the septum secundum type are usually repaired by direct suture and do not require a patch of foreign material for closure (Fig. 34). For ostium primum or low defects a compressed Ivalon patch is usually employed to avoid distortion and tension on the inferior rim of the opening in which the atrioventricular conduction bundle is located since total heart block may result (Fig. 35). Clefts in the mitral and tricuspid valves may be repaired at the time of repair of the septal opening. Results of operation are usually excellent (Fig. 36). Under most circumstances a mortality rate of less than 5 per cent is expected unless patients with severe pulmonary hypertension or advanced cardiac failure are included, in which case the risk of operation is increased.

PATENT DUCTUS ARTERIOSUS

The ductus arteriosus is a vascular communication between the pulmonary artery near its bifurcation and the aorta just beyond and opposite the origin of the left subclavian artery (Fig. 37). Its embryologic development has been discussed in the preceding sections. Normally patent during intrauterine life, the ductus serves an essential function in fetal circulation by permitting the the shunting of most of the blood from the pulmonary to the systemic circulation, owing to the fact that during this period the unexpanded lungs are functionless and the pulmonary pressure is relatively high. Following

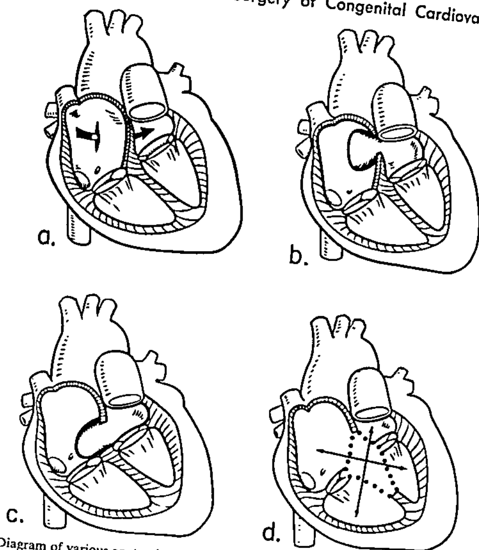


Fig. 33. Diagram of various anatomic types of atrial septal defect showing: a, patent foramen ovale; b, septum secundum defect; c, ostium primum defect; and d, an atrioventricularis communis or atrioventricular canal.

upon the same principle used in selection of patients with ventricular defect. The presence of a large left-to-right shunt with mild or moderate increase in pulmonary vascular resistance is the best indication for operation. The optimum age for operation is five to fifteen years. In some atrial defects, particularly the ostium primum and atrioventricularis communis, severe cardiac disturbance may be present during infancy and early childhood and operation must be performed early.

A number of technics were used in the past to close atrial defects by closed technics, i.e., without actually opening the heart. Atrioseptopexy (Bailey) and circumclusion (Sondergaard, Crafoord, and Björk) were typical of these methods in which the walls of the dilated right atrium were brought into the repair. Other modifications of these technics were used but are gradually being discarded in favor of open technics. An ingenious semiopen method was used in which a rubber funnel was sutured to the side of the right atrium (Gross). Upon opening the atrium the atrial well filled with blood and repair of the defect was accomplished in the depths of the pool of atrial blood. Recently more satisfactory methods of repair have been devised in which the heart is opened for repair under direct vision using general body hypothermia or temporary cardiopulmonary bypass and a pump oxygenator. By the former technic body temperature is reduced artificially under general anesthesia by cooling blankets or by immersion of the pa-

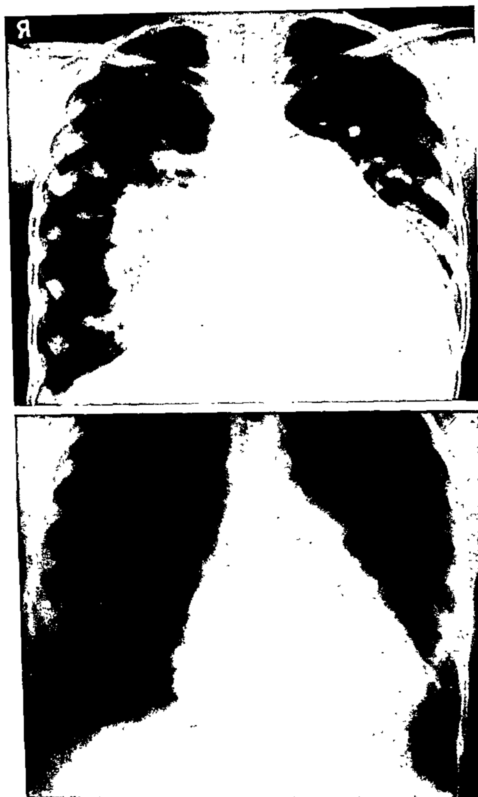


Fig. 36. Roentgenograms of chest in 12-year-old girl. Above, before operation. Below, nine months later, showing reduction in cardiac size and pulmonary vascularity following complete closure of an atrial septal defect.

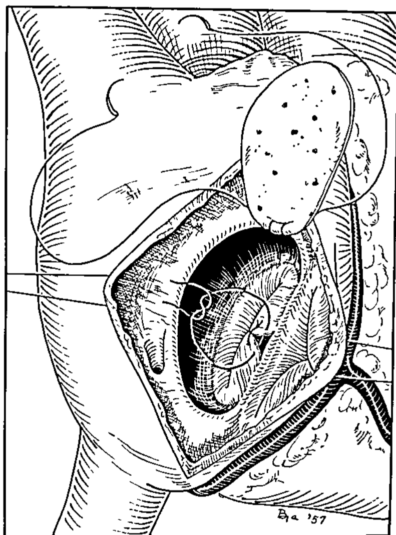


Fig. 35. Drawing showing technic of repair used in ostium primum defect with cleft mitral valve. After the mitral cleft is repaired, the defect is closed with a patch of synthetic material.

birth, however, the lungs expand and assume function, and blood flow through the lungs becomes necessary for oxygenation. The shunting of blood from the pulmonary bed through the ductus arteriosus then becomes unnecessary as well as undesirable. Although this vessel is normally patent at birth, it soon undergoes obliteration after birth and in most individuals is completely closed within a few weeks to a few months. In some instances, however, closure of the ductus may be delayed for as long as six months to two years. Its failure to close beyond this period constitutes an abnormality and may produce serious disturbances.

In this connection, persistent patency of the ductus may be associated with other congenital cardiac abnormalities, such as complete pulmonary atresia, coarctation, truncus arteriosus, and transposition of the great vessels. Its failure to close under some of these circumstances represents a different problem since it may thus serve an essential function in maintaining life by providing blood flow to the lungs. Reference to its association with these conditions is made elsewhere and this section is devoted to its occurrence as an isolated abnormality.

Although various theories have been proposed to explain the mechanism by which normal closure of the ductus takes place, none is entirely satisfactory. According to some observers, normal closure of the ductus represents an inherent tendency through certain basic characteristics of its tissue. This may be effected through a reflex mechanism,

patient has reached adult life, although on close questioning many of these patients recall their inability to keep up with their playmates during childhood. Less commonly, manifestations of frank cardiac failure occur.

Physical findings in this condition are usually so characteristic that the diagnosis can often be made on this basis alone. The most striking finding, which may be considered pathognomonic, is the presence of a continuous "machinery" murmur. It is usually heard best in the second or third interspace just left of the sternal border and has a harsh, rasping, rumbling quality. Continuous throughout both systole and diastole, the murmur is greatly accentuated during systole, and this element of the murmur may be transmitted widely over the precordium and into the neck, axilla, or back. In many cases, a thrill, similar in location and quality to the murmur, may be elicited. In some instances and particularly those with a high pulmonary pressure, the typical continuous murmur may not be present and only a systolic murmur may be heard.

Characteristically, the heart tends to be normal in size or only slightly enlarged. The blood pressure may be entirely normal but more often tends to show an increased pulse pressure with a slightly decreased diastolic pressure which may become more pronounced on exercise, particularly in cases with a large ductus.

Laboratory findings including electrocardiographic studies are usually within normal limits. Occasionally, in patients with beginning cardiac embarrassment, the electrocardiogram may show left axis deviation. Roentgenographic examination of the chest may show little or no abnormality, particularly if the ductus is small. In most cases, however, certain characteristic features may be recognized. The transverse dimension of the heart tends to be slightly to moderately increased and the pulmonary artery shadow along the left sternal border may be somewhat more prominent than normal (Fig. 38). The pulmonary vascular markings, particularly in the hilar regions, may be accentuated. Fluoroscopy may reveal more conspicuous pulsation of the pulmonary artery, and in some cases with a large shunt, a "hilar dance" produced by the increased amplitude of pulsations in pulmonary arteries may be observed.

The diagnosis of patent ductus arteriosus is not difficult in the great majority of cases and can be made on the basis of the characteristic manifestations, particularly the auscultatory findings described above. The major difficulty in diagnosis arises in the occasional cases in which the characteristic continuous murmur is not present. Under these circumstances further studies, including angiocardiography and cardiac catheterization, may be necessary to determine the correct diagnosis.

Treatment. Surgical closure or obliteration of the ductus constitutes effective treatment. This may be accomplished by simple ligation, but division and suture is the preferred method (Fig. 39). The risk of operation in uncomplicated cases is minimal, with an operative mortality of less than 2 per cent. In light of the potential hazards of this condition and the minimal risk of operation, operative treatment is recommended in all cases whether or not symptoms are present, except in the asymptomatic individual beyond the sixth decade of life. Unless symptoms occur, it is preferable to delay operation in infants until the child has reached the age of three or four years. In the presence of subacute bacterial endocarditis, preliminary penicillin therapy should be employed and operation performed about six months later if an effective response is obtained; if not, early operative treatment is indicated.

Under certain circumstances operative closure of the ductus may be inadvisable. These include particularly those associated with severe degrees of pulmonary hypertension with reversal of flow through the ductus or with other noncorrectable cardiac malformations in which the ductus is serving as a compensatory mechanism. With the use of open heart surgery by means of the artificial heart lung apparatus, some of these abnormalities associated with patent ductus are now amenable to operative treatment. In the presence, however, of a pulmonary artery pressure that approximates or exceeds systemic pressure, operation is probably inadvisable.

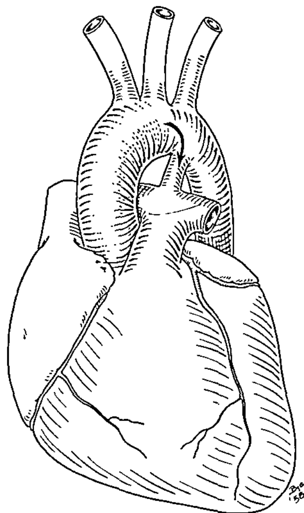


Fig. 37. Drawing showing anatomic relationship of patent ductus arteriosus.

possibly by way of the vagus nerve or by certain chemical constituents of the blood, particularly oxygen. Still another theory is based upon changes in anatomic relationship of the mediastinal structures which take place following birth and expansion of the lungs. While the role of these and perhaps other factors in initiating closure of the ductus is not entirely clear, its actual obliteration apparently results from certain characteristic morphologic changes which take place in the vessel consisting essentially in proliferation and thickening of the intima and media.

Persistent patency of the ductus arteriosus beyond the first year or two of life produces certain physiologic disturbances characteristic of an arteriovenous fistula. As indicated above, during fetal life the gradient of pressure in the pulmonary and systemic circulation permits blood to be shunted from the former to the latter circuits. Following birth, however, a reversal in this gradient of pressure takes place with an increase in aortic pressure and a decrease in pulmonary artery pressure. As a consequence, blood flow through the patent ductus is also reversed and is directed from the aorta to the pulmonary artery. The volume of flow through this abnormal channel is variable, depending upon the size of the ductus and the pressure gradients in the two circuits. The amount of blood which may be shunted in this manner has been studied by a number of observers who have found that it may range from about 2 to almost 20 liters per minute. According to these investigations, the volume of blood thus shunted may represent from 45 to 70 per cent of the total left ventricular output. Obviously, the major consequence of this abnormal blood flow from the systemic to the pulmonic circuits is to impose an increased workload upon both ventricles.

Although this physiologic disturbance in circulation may be well tolerated in some individuals, particularly in the presence of a relatively small shunt, in most cases it is associated with certain disturbances and complications that may have serious import. These include particularly retardation in growth and development owing to diminished peripheral blood flow, cardiac embarrassment, or failure as a result of the increased workload on the heart, and infection usually with *Streptococcus viridans* with the production of subacute bacterial endocarditis.

Clinical Considerations. For undetermined reasons, this malformation occurs somewhat more frequently in females than in males, the respective ratio being about two or three to one. Symptoms produced by the lesion are variable depending upon the size of the ductus, the amount of blood shunted through it, and the occurrence of complications. In some cases no significant manifestations occur and the patient may lead a normal existence well into an advanced age. More often, however, there develop mild to moderate degrees of cardiac disturbances manifested by dyspnea, palpitation, and tachycardia, especially following excessive exercise. Easy fatigability and poor exercise tolerance may become apparent only after the

Fig. 39. Drawing illustrating method of surgical treatment of patent ductus arteriosus by division and suture.

Fig. 40. Diagram showing types of anomalous drainage of pulmonary veins: a, partial anomaly of the right pulmonary vein is present, emptying into right atrium. In b and c are shown the commonest types of total anomalous drainage of pulmonary veins.



Fig. 38. Roentgenogram of chest in patient with patent ductus arteriosus showing characteristic features of slight increase in transverse dimensions of heart, increased prominence of pulmonary artery shadow along left sternal border and somewhat accentuated pulmonary vascular markings.

ANOMALOUS DRAINAGE OF PULMONARY VEINS

Drainage of pulmonary venous blood into the right atrium or into the systemic veins produces a left-to-right vascular shunt with physiologic effects similar to atrial septal defect. Indeed, in most instances, anomalous pulmonary venous drainage and atrial septal defect occur concomitantly. Although at one time considered to be rare, Brody's review of 106 collected cases in 1942 focused attention upon this anomaly; and recently such anomalies have proved to be common abnormalities. The type of lesion may vary in many respects depending upon whether partial or total anomalous pulmonary drainage is present and upon the location of entry of the abnormal communication (Fig. 40).

Partial anomalous drainage usually occurs from the right lung in which the connection is into the superior vena cava, right atrium, or inferior vena cava. Partial anomalous venous drainage from the left lung is less common than right pulmonary anomalies. In right sided anomalies drainage into the superior vena caval system by a trunk leading to the left innominate vein is the predominant type. In many instances, anomalous drainage may occur at more than one point. Differential diagnosis between partial transposition of anomalous veins and an interatrial septal defect may be difficult even with the use of cardiac catheterization because in both situations oxygenated blood is present in the right auricle, right ventricle, and pulmonary artery. In most instances of partial anomalous pulmonary venous drainage, the volume of left-to-right shunt is less than in the average atrial septal defect. Usually the volume of left-to-right shunt does not exceed

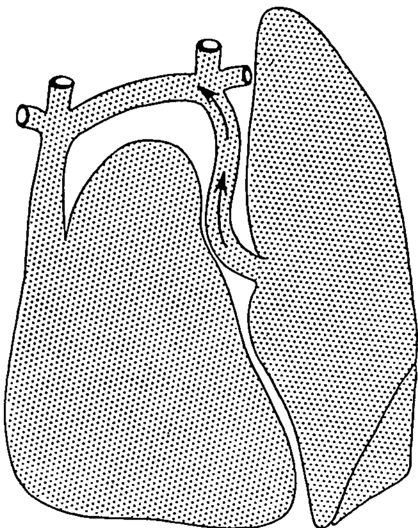


Fig. 41. (Cont.) Diagrammatic representation of x-ray on facing page.

lesion is incompatible with life. In most instances this communication is a patent foramen ovale or septum secundum type of atrial defect. Prognosis in most instances is poor and death usually occurs during the first few months of life unless surgical correction is undertaken. Cyanosis may occur with total anomalous venous drainage since mixed venous and arterial blood must gain access to the left atrium via an atrial septal defect. In some patients, therefore, and particularly in those with a large atrial communication, cyanosis may be severe. In general, however, the larger the atrial defect the better the prognosis for survival.

Surgical treatment of anomalous pulmonary venous return may not be necessary if only a single segmental pulmonary vein empties anomalously, such as is common with the right upper lobe draining into the superior vena cava. When the volume of drainage is large and an entire lobe or more drains anomalously, indications for surgical correction are the same as for atrial defects. At present partial anomalous pulmonary drainage is relatively simple to repair during cardiopulmonary bypass by open cardiac technics. In most instances the anomaly is repaired by transposing the septum during repair of the associated patent foramen or atrial septal defect. In instances in which the left lung drains separately into the left in-



Fig. 41. Roentgenogram of chest in patient with anomalous pulmonary venous drainage of entire left lung. Tortuous venous trunk ascending in left mediastinum produces configuration known as "snowman" configuration. (See diagram on facing page.)

50 per cent of total pulmonary flow, whereas shunts of 70 to 85 per cent are not uncommon with atrial septal defects. When the partial drainage is into the left innominate vein, the presence of blood of high oxygen saturation in this vessel may confirm the diagnosis at the time of cardiac catheterization.

Partial anomalous pulmonary venous drainage may be associated with an excellent prognosis depending upon the volume of shunt produced. If a significant shunt exists, the same clinical symptoms and findings are present as for atrial septal defect. Cyanosis is not characteristically a feature of this anomaly. Total anomalous drainage may exist in several anatomic types. In the most common type the pulmonary veins enter a common venous trunk which empties into the superior vena caval system via the left innominate vein (Fig. 41). Drainage may occur directly into the right atrium as a separate posterior opening or may join the coronary sinus and empty with coronary venous blood into the coronary sinus ostium. In a rare type of drainage the pulmonary venous trunk enters the inferior vena caval system usually connecting with the hepatic vein. In all cases of total anomalous venous drainage, an intracardiac communication between right and left sides must be present, otherwise the

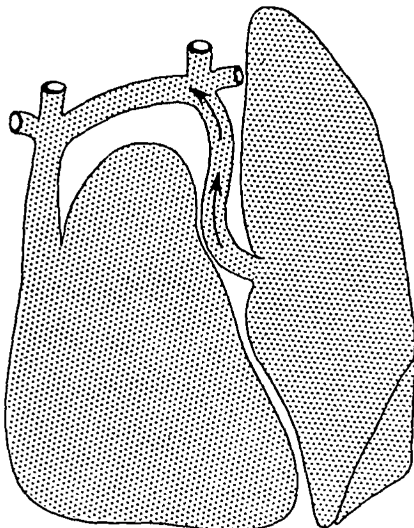


Fig. 41. (Cont.) Diagrammatic representation of x-ray on facing page.

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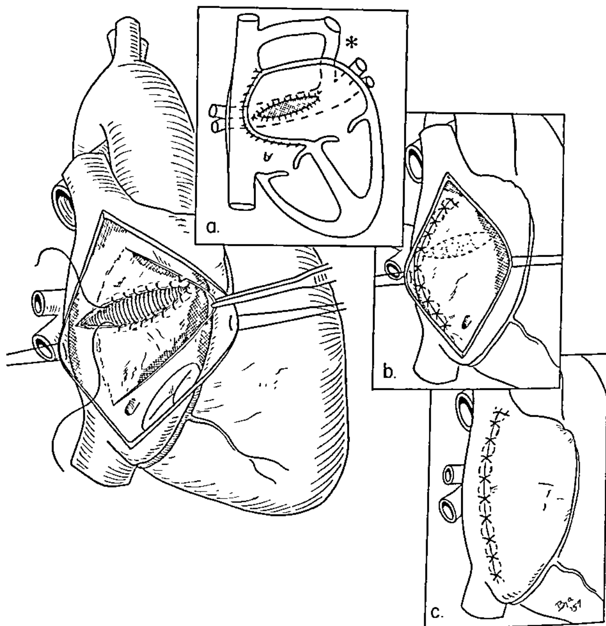


Fig. 42. Drawing showing method of repair of total anomalous drainage of pulmonary veins. Implantation of the common venous trunk into the posterior aspect of the left atrium is accomplished using cardiopulmonary bypass. Common pulmonary venous trunk* is ligated in superior mediastinum after anastomosis is completed.

nominate vein, this connection may be divided and the vein anastomosed directly into the left auricular appendage without using cardiopulmonary bypass (Fig. 42).

Surgical correction of total anomalous pulmonary venous drainage must be done, using temporary cardiopulmonary bypass. Depending upon the type of anomaly this may be accomplished by repositioning the atrial septum toward the right in order to permit entry of the veins into the left atrium. In the most common form of total anomaly the common venous trunk entering the superior vena cava is ligated and an anastomosis between the retrocardiac vessel and the left atrium must be done. Several successful cases of this difficult type of repair have recently been reported, indicating that virtually all cases of anomalous pulmonary venous drainage are now amenable to surgical correction.

SINUS OF VALSALVA FISTULA

Rupture of an aneurysm of the sinus of Valsalva at the root of the aorta is a rare cardiac lesion which may lead to development of a fistulous communication between the aorta and a cardiac cavity. Usually the rupture occurs into the right ventricle or right atrium, producing a left-to-right circulatory shunt. Not all aneurysms of the sinus rupture. They may persist as more or less silent lesions. The aneurysm itself represents a congenital defect in the aortic annulus and its sinuses of Valsalva, but rupture usually does not occur until after the first few years of life. At the site of the aneurysm the aortic media does not contribute to the wall of the sinus, and the sinus wall is formed by surrounding tissues, usually the right atrium or right ventricle. These tissues are incapable of withstanding aortic pressure and subsequently an aneurysm is formed.

Sinus of Valsalva fistula produces striking physical findings, being associated with aortic insufficiency and a circulatory shunt. Thus, a loud systolic and diastolic murmur of almost machinery quality is audible along the left sternal border. This finding, together with a widened pulse pressure, makes this condition easily mistaken for patent ductus arteriosus. Other conditions from which the lesion must be differentiated are anomalous communication of a coronary artery with coronary vein, coronary sinus, or atrial cavity.

Cardiac enlargement usually occurs and ultimately left ventricular failure ensues. Diagnosis may be made by retrograde aortography, and cardiac catheterization is useful to locate the position of the fistulous opening.

Surgical treatment has been reported in a small number of patients in whom open cardiac technics were used for temporary cardiopulmonary bypass. Right ventriculotomy or atriotomy is used to expose the intracardiac fistulous opening for repair. Sometimes after repair of the fistula aortic regurgitation persists.

AORTICOPULMONARY SEPTAL DEFECT

A congenital defect of the aortic septum producing free communication between the ascending aorta and adjacent main pulmonary artery is a rare anomaly often producing serious physiologic disturbance and a massive left-to-right shunt. Several descriptive terms have been suggested for this lesion, including aorticopulmonary septal defect, aorticopulmonary fistula, and aortic window or fenestration. Until recently clinical diagnosis was not possible, but with developments in angiography, aortography, cardiac catheterization, and dye dilution studies the diagnosis may be made with some accuracy. Usually the expected continuous murmur is not present and only a systolic murmur with accentuated pulmonary second sound is heard.

Surgical repair of the lesion without cardiopulmonary bypass is hazardous and death from hemorrhage is a serious threat. Recently the complete repair of aorticopulmonary septal defect with cardiopulmonary bypass has been successful and is now considered the method of choice in such lesions.

COR TRIATRIATUM

In this rare anomaly the left atrium is divided by a septum into two chambers. One or more openings must exist in the septum in order for the patient to survive. In patients with a large communication, no symptoms may be manifest and the lesion is an incidental finding at autopsy. If the opening is sufficiently small to produce significant obstruction to pulmonary outflow, a clinical picture similar to mitral stenosis may be produced. When a patent foramen ovale is also present, a right-to-left shunt is produced and cyanosis may result.

The most logical embryologic explanation of this anomaly is that it represents a failure of the embryologic common pulmonary vein to incorporate normally into the posterior aspect of the left atrium. The third chamber is nothing more than a dilated common pulmonary vein. Surgical treatment has been made possible by the technics of open heart surgery including both general body hypothermia and temporary cardiopulmonary bypass with pump oxygenator.

EBSTEIN'S DISEASE

This anomaly consists of a downward eccentric displacement of the tricuspid valve into the right ventricle. The anterior leaflet

of the tricuspid valve is usually normally placed and the septal leaflet is attached to the ventricular septum in an anomalous manner. The septal leaflet may be functionless but in many instances forms an obstructive flap to outflow of the right ventricle. The posterior leaflet arises below the annulus usually having no connection with the atrioventricular ring. Considerable variation usually exists in the number and position of papillary muscles and chordae tendinae.

As a result of the downward displacement of the valve, a portion of the right ventricle becomes a functional part of the right atrium. A patent foramen ovale is common, and because of the increased right atrial pressure produced by tricuspid incompetence, a right-to-left shunt and cyanosis result. Dyspnea, cardiac enlargement, and signs of right sided failure are common in this malformation. Although some patients live into adulthood, prognosis is usually poor and sudden death is frequent.

Surgical treatment has been attempted by Kirklin and associates with some success. Closure of an interatrial communication may relieve cyanosis. Relief of outflow obstruction in the right ventricle by revising the septal leaflet of the tricuspid valve may enhance right ventricular propulsion and relieve cardiac failure to some degree. Nevertheless, results are still somewhat equivocal and because of the complex nature of the lesion indications for operation are controversial.

COMPLETE TRANSPOSITION OF THE GREAT VESSELS

In this anomaly the aorta arises directly from the right ventricle and the pulmonary artery from the left. Various theories have been advanced for the cause of this developmental abnormality which indicate that improper rotation and torsion of the aortic septum and great vessels result in failure to fuse properly with the upper margin of the ventricular septum. This condition leads to a severely cyanotic state since unoxygenated venous blood entering the right ventricle is pumped directly into the aorta. Oxygenated blood from the pulmonary veins enters the left atrium, after which it enters the left ventricle and is returned to the pulmonary circulation via the pulmonary arteries (Fig. 43). In order for this lesion to be compatible with life even for a short time, some communication between the systemic and pulmonary circuits must be present to permit interchange of oxygenated and unoxygenated blood. Three possible communications are a patent foramen ovale, a patent ductus arteriosus, or a ventricular septal defect. The foramen ovale and ductus arteriosus are normally patent before birth but have a tendency to close after birth, leading to increased cyanosis. A ventricular septal defect is a more effective type of shunt in these patients for relief of cyanosis, since it has no tendency to close spontaneously. The majority of patients with uncomplicated transposition usually have a combination of two or even all three of these associated defects.

Prognosis in complete transposition of the great vessels is poor. Lillehei and Varco reported only 4 per cent of patients in collected series were alive at seven years of age and 78 per cent of the group died during the first year of life. Cyanosis may or may not be present at birth but becomes evident and intense shortly thereafter, particularly if the cardiac septa are intact. If an adequate interchange of blood between the two sides of the heart is present, it is remarkable how normal the infant may appear except when crying. Sooner or later in complete transposition the cyanosis usually becomes intense. Underdevelopment and malnutrition are almost inevitable if the patient survives the first six months of life. Long, thin fingers with almost flail interphalangeal joints are typical and severe clubbing of the nails is common.

Physical examination usually reveals cardiac enlargement. Murmurs are variable and not diagnostic since they may reflect changes in intracavitary pressure, valvular defects, and varying direction of shunts. Cardiac failure usually is present in varying degree, manifested by hepatomegaly and distended pulsatile neck veins. Death is usually caused by anoxemia or cardiac failure. Cerebral infarctions and abscesses are an occasional cause of death.

Roentgenographic examination reveals cardiac enlargement of both right and left ventricles with a waistlike narrowing at the base due to the alignment of ascending aorta

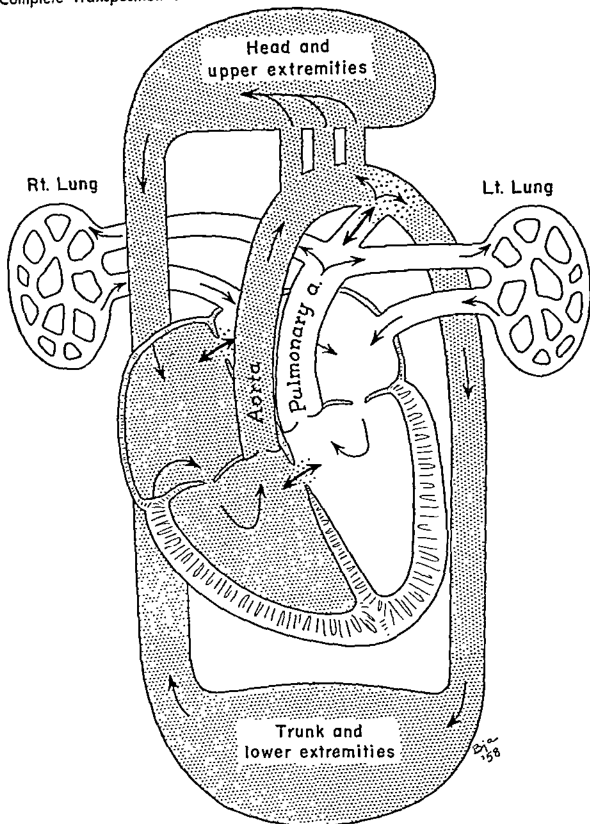


Fig. 43. Diagram showing course of circulation in complete transposition of great vessels. Since the aorta arises directly from the right ventricle, unoxygenated blood gains ready access to the systemic arterial system.



Fig. 44. Roentgenograms of chest in patient with complete transposition of great vessels. Above, an anteroposterior film shows the narrow superior mediastinum, vascular lung fields, and cardiac enlargement; below, an angiocardiogram in lateral position reveals anterior position of aorta arising from the right ventricle.

and pulmonary artery in the anteroposterior projection. Usually pulmonary vascular markings are accentuated. Angiocardiography in the lateral view shows a characteristic anterior position of the ascending aorta arising from the right ventricle (Fig. 44). Electrocardiograms show right ventricular hypertrophy usually with right axis deviation, but since the left ventricle may also be hypertrophied a normal electrical axis may be present.

Surgical repair of complete transposition of great vessels continues to challenge cardiac surgeons. Blalock and Hanlon reported creation of an interatrial septal defect to provide an intracardiac communication. This technic may be accomplished by closed cardiac technics and is still considered to be the simplest and possibly most effective of the palliative procedures. Others including Varco and Lillehei, and Baffes have tried transposition of venous inflow to compensate for the anomalous origin of the aorta and pulmonary artery. Although palliation with improvement in cyanosis has resulted in some instances of partial correction by transfer of venous inflow, results have not been particularly encouraging and operative mortality is high. An ideal operation which would totally correct the anomaly could theoretically be done by changing the origin of the arterial outflow or by transposing venous inflow. Recently the pump oxygenator has been used with attempts at repair, using both of these technics, but to date not a single survivor of total correction of complete transposition of the great vessels has been reported.

EISENMENGER COMPLEX

In this anomaly a dextroposed aorta which partially overrides the ventricular septum is associated with a high ventricular septal defect. Thus in some respects the anomaly resembles tetralogy of Fallot, but pulmonary stenosis is not present. Pressure in the two ventricles is similar and accordingly pressure in the pulmonary artery is elevated. The direction of flow through the ventricular defect depends upon the relative resistance in the pulmonary and systemic circuits. Sclerotic and obliterative changes in the pulmonary arterioles lead to a severely elevated pulmonary resistance, and a right-to-left shunt occurs at the ventricular level, ultimately producing cyanosis.

Cyanosis is usually absent in infancy and childhood. The subsequent development of cyanosis during adolescence is frequently diagnostic of Eisenmenger complex. Clubbing of the fingers and toes is relatively slight, since the degree of anoxemia is minor compared to other cyanotic heart diseases. Hemoptysis occurs in advanced cases. Cardiac findings are variable, but right ventricular hypertrophy is always present. A systolic murmur may be present and an accentuated pulmonary second sound is typical. Increased pulmonary pressure may lead to a functional incompetence of the pulmonary valve manifested by a Graham Steell murmur. Although hilar pulmonary vessels are large roentgenographically, peripherally the lungs may appear ischemic, due to the reduced arteriolar flow.

Surgical treatment of this lesion in its advanced stages is not possible because the pulmonary vascular resistance prevents repair of the ventricular defect. The interventricular defect serves as a safety valve releasing blood in the right ventricle into the aorta, thus preventing right side congestive failure. Drugs for reducing pulmonary hypertension will probably be developed and symptomatic relief may result, but at present oxygen inhalations are the only effective method of providing relief of symptoms.

TRUNCUS ARTERIOSUS

This anomaly is characterized by the presence of a single great vessel of large caliber which receives all of the blood from both ventricles. Blood is directed from the truncus to the systemic and pulmonary circulations. Pulmonary circulation may be derived from the trunk directly or from collateral channels developed from bronchial arteries. Coronary arteries arise from the base of the common trunk which, after giving off vessels to supply the lungs, continues as the aorta to the systemic arterial system. Since the truncus arises from both ventricles, it overrides the ventricular septum. A ventricular septal defect is therefore an integral part of the malformation. The malformation causes cardiac enlargement and hypertrophy of both

ventricles. Pulmonary hypertension is frequently a sequela to this defect.

Satisfactory surgical treatment of this lesion in its true form is not possible at present. Because of lack of sufficient cuspal tissue in the aortic and pulmonic valves, creation of separate valves and main vessels does not appear to be feasible.

ENDOCARDIAL FIBROELASTOSIS

Thickening of the mural endocardium by elastic and collagenous connective tissue characterizes the primary pathologic derangement of endocardial fibroelastosis. The left ventricle is most commonly involved, although a similar process has been described in all cardiac chambers. The etiology remains uncertain although numerous causative factors have been suspected.

On the basis of its appearance two types of endocardial fibroelastosis of the left ventricle may be distinguished: the contracted type and the dilated type. The final result is a thickened endocardium limiting expansion and contraction of the left ventricle. Progressive impairment in pulmonary venous drainage produces effects on the pulmonary circulation and right ventricle similar to those of mitral stenosis. Survival beyond early childhood is uncommon.

There is no satisfactory treatment for this condition.

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SURGERY OF ACQUIRED CARDIOVASCULAR DISEASE

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WOUNDS OF THE HEART

Wounds of the heart have attracted interest since the beginning of civilization. In the ninth century B.C., Homer described vividly the movement of the human heart transmitted through a spear: "The hero Idomeneus smote him in the midst of the breast with the spear. . . . And he fell with a crash, and the lance fixed in his heart, that, still beating, shook the butt end of the spear." The ancients considered wounds of the heart necessarily fatal, a concept that predominated until the end of the last century. Important isolated advances, however, had been made before that time. In 1761 Morgagni pointed out the danger of compression of the heart due to hemorrhage into the pericardium and thus originated the concept of pericardial tamponade. Larrey, Napoleon's surgeon, is credited with performing the first successful pericardicentesis in 1829.

Types. PENETRATING WOUNDS. These are the most frequently encountered cardiac wounds among civilian patients who do not die immediately. They are made by knives, icepicks, and other sharp instruments. The site of entry most commonly is the left parasternal region in the precordial portions of the second through the seventh ribs. Because of its vulnerable anterior position, the right ventricle is injured more than twice as often as the left ventricle (Fig. 1). Less frequently injured are the atria and the intrapericardial portions of the great vessels. The predominance of penetrating over perforating injuries has also been observed in military surgery. In 2,811 chest casualties of the Korean conflict treated at Tokyo Army Hospital, 117 had injuries of the heart and mediastinum. In the latter group, 90 per cent were penetrating wounds usually caused by shell fragments.

PERFORATING WOUNDS. These are characteristically produced by bullets. Usually there are two or more perforations in one or more cardiac chambers. Generally, cardiac wounds inflicted by large caliber firearms are immediately fatal, but patients with wounds caused by smaller caliber weapons sometimes live long enough to permit transportation to emergency centers. Gunshot wounds may enter the heart from any direction.

CLOSED INJURIES OF THE HEART. Types of closed cardiac injury include: 1. direct contusion from forces exerted against the wall of the chest or spine; 2. tearing injuries associated with the suspensory anatomy of the heart; 3. concussion producing multiple

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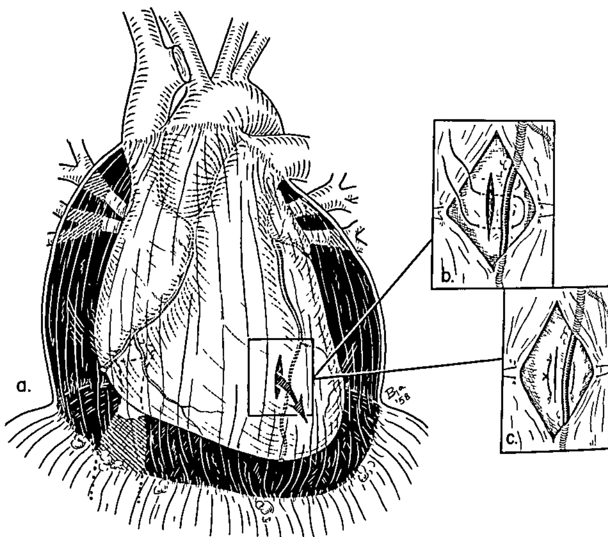


Fig. 1. a, schematic drawing of the heart and pericardium showing the effect of cardiac tamponade. Increased intrapericardial pressure compresses the venae cavae and pulmonary veins impeding venous return of blood to the heart. b, method of suture repair of wound adjacent to anterior descending branch of left coronary artery. c, tied horizontal mattress suture closes ventricular wound but does not impair blood flow through the coronary artery.

minute hemorrhages and often alterations in the autonomic control of the heart; 4. intracavitary pressure changes within the heart due to compression of distant parts, such as the abdomen and extremities; 5. subintimal coronary hemorrhages usually associated with atheromatous plaques and resulting in reduction of the lumen of the coronaries; and 6. secondary myocardial changes associated with shock, hemorrhage, and stress. In spite of Beck's prophetic writings on cardiac contusion in 1935, there remains general lack of awareness of this common injury among physicians. Indeed, in most hospital record libraries, this diagnosis is infrequently recorded. The most common cause of such injuries is the automobile steering wheel. In our experience, significant electrocardiographic changes almost invariably are demonstrable in patients with steering wheel injuries associated with external evidence of precordial contusion when serial tracings are performed. These electrocardiographic alterations may vary from minor T-wave depression to a picture of severe myocardial infarction. The changes may persist for weeks or months, and in an occasional patient exertional angina persists indefinitely. Usually, cardiac injuries from blunt force cause only myocardial contusion and recovery is uneventful. The medicolegal implications of such injuries, however, will undoubtedly become a significant problem. Such injuries may rupture the pericardium, myocardium,

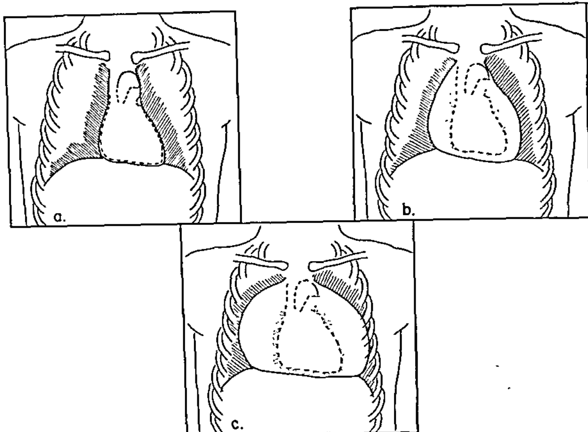


Fig. 2. Schematic drawing of cardiac silhouette in: a, normal condition; b, acute cardiac tamponade; and c, chronic pericardial effusion. The inelastic fibrous pericardium does not allow the massive pericardial enlargement in acute tamponade common with chronic effusion or delayed tamponade.

cardiac septa, or valves. Delayed hemopericardium may produce cardiac tamponade. Constrictive pericarditis may present a late complication. An unusual type of closed cardiac trauma is exemplified by the recent report of a man caught in a sand cave-in and buried only to the level of the waist. He died instantly and post-mortem findings included laceration of the interventricular septum and papillary muscles of both ventricles.

Clinical Considerations. Successful therapy of cardiac wounds depends on timely diagnosis. Few surgical emergencies require such prompt clinical evaluation. In such emergencies, sometimes successful treatment will depend on a diagnosis derived from a single glance at a moribund patient with a precordial wound. The diagnosis, however, is often not obvious and sometimes can be made only if the examiner is constantly aware of this possibility. Important also is a thorough understanding of the hemodynamic alterations associated with cardiac wounds. The lethal factors, in order of frequency, are pericardial tamponade, exsanguinating hemorrhage, and intrinsic cardiac damage. The physiologic derangement of cardiac tamponade results from collection of blood in the relatively inelastic pericardium, producing interference with return of blood from the venae cavae and pulmonary veins (Fig. 2). The critical level of pericardial pressure, as determined in our laboratory, is 20 cm. of saline. If such pressure is even slightly increased in the experimental animal, venous pressure and pericardial pressures become equalized, arterial pressure rapidly falls, and cardiac action ceases. These studies in reverse demonstrate the resuscitative effect of pericardicentesis in cardiac tamponade and strikingly reveal that as little as 5 to 10 ml. of aspirant has immediate influence upon recovery of circulation.

Beck proposed the diagnostic triad of the

quiet heart, increased venous pressure, and hypotension. Other classic signs of pericardial tamponade include a narrow pulse pressure, dusky cyanosis, and a decreased pulse rate. Roentgenograms provide less diagnostic information in acute tamponade than in the chronic form, since the relatively inelastic pericardium does not immediately become greatly distended. In chronic or delayed tamponade, an enormous cardiac silhouette is frequently demonstrated roentgenographically, and several liters of bloody fluid can often be aspirated (Fig. 2). In an occasional doubtful case of acute tamponade, fluoroscopy may be of value.

If the opening in the pericardium is adequate for the egress of blood, no tamponade will occur and clinical signs will be those of hemorrhagic shock. In addition, occasionally there is a picture of deranged pulmonary function due to massive hemothorax or pneumothorax. Rarely, valvular and septal ruptures are immediately evident. In most instances such intracardiac derangements become apparent several days after injury with the appearance of murmurs or cardiac failure. Blunt trauma to the heart may produce direct myocardial damage from contusion or from ischemia associated with damage to the coronary artery. In such cases, there may be no signs of tamponade and hemorrhage, and hypotension may be the only presenting sign. Often the heart tones may have a "tick tick" quality due to epicardial and pericardial injury. Shock from cardiac contusion is less favorably responsive to intravenous administration of fluids and vasopressor agents. Electrocardiographic alterations may vary from minor T-wave depression to those of massive myocardial infarction.

Treatment. The first successful suture of a human cardiac wound was performed by Rehn in 1896. Within 10 years after this pioneering achievement, it was possible to collect 124 cases of cardiorrhaphy with recovery in 40 per cent of the patients. Until the past decade emergency cardiorrhaphy was generally considered the treatment of choice in cardiac wounds, and in this country a number of surgeons accumulated wide experience with this method of treatment. The operative mortality rate, however, remained high, ranging from 30 per cent to more than 50 per cent. Although pericardicentesis had been employed previously, the rationale of this method combined with replacement of blood and other fluids as definitive treatment in cardiac injuries was first recommended by Blalock and Ravitch in 1943. Since then, several reports of such management have indicated a mortality rate below that of cardiorrhaphy. Obviously, not all cardiac wounds are amenable to conservative management, and cardiorrhaphy may be necessary for survival. If the best of previous clinical experience is to be applied to the individual patient, keen surgical judgment must be exercised in the choice of conservative versus operative management or the combination of these modalities.

Emergency treatment of cardiac injuries is based upon prompt relief of pericardial tamponade. When the pericardial pressure reaches 20 cm. of saline or more, aspiration of as little as 5 to 10 ml. has an immediate influence upon recovery of circulation. Commonly, pericardicentesis is necessary only once, because patients with penetrating injuries who survive long enough to reach a hospital usually have small wounds. These tend to become sealed by clots with the aid of pericardial tamponade. Pericardial aspiration may be performed repeatedly if signs of recurring tamponade appear. Blood lost by aspiration is replaced by transfusion, and occasionally continuous autotransfusion of aspirated blood may be lifesaving while preparations for cardiorrhaphy are being made. Incoagulable blood from pericardicentesis is assumed to have come from the pericardial sac, whereas if a coagulum forms, the blood may have been withdrawn from a cardiac chamber. The paraxyphoid route for aspiration is preferable to precordial interspace approaches because coronary injury is less likely.

In previous years intravenous administration of blood and other fluids was thought to be contraindicated since they elevate venous pressure and tend to increase the constricting force of intrapericardial fluid pressure. It has been repeatedly demonstrated experimentally and clinically that intravenous administration of fluids tends to increase arterial pressure. Vasopressor agents also have a favorable in-

fluence on arterial pressure in the presence of pericardial tamponade.

One must always be prepared to perform cardiorrhaphy since a significant number of patients will continue to bleed profusely. An incision in the left anterior fourth or fifth interspace permits rapid entrance into the chest with adequate exposure. Torrential hemorrhage may be controlled with a finger or sponge over the wound, but the friable myocardium may be further torn if a finger is placed through the defect. In wounds adjacent to the anterior descending branch of the left coronary artery, an on-end mattress suture may preserve the vessel. The pericardium should be left open or closed loosely to avoid delayed collections of pericardial fluid. It must be pointed out that, in at least two centers where large numbers of penetrating injuries of the heart are treated, primary surgical repair is still favored over initial conservative management.

Closed injuries of the heart with contusion are treated essentially the same as is myocardial infarction. The period of bed rest is properly governed by the time necessary for the electrocardiographic changes to return to normal.

Periodic observation of all patients with cardiac injury is essential. Delayed effusion and chronic tamponade may develop months after the initial injury. Traumatic intracardiac shunts and valvular injuries may not be evident for days after the injury. Such intracardiac defects are now amenable to definitive open repair using cardiopulmonary bypass. Some retained foreign bodies within the heart or pericardium must be removed.

CHRONIC CONSTRICTIVE PERICARDITIS

Chronic constrictive pericarditis is a disease involving thickening and contraction of the pericardium or epicardium with the hemodynamic alterations associated with an imprisoned and restricted heart. The principal circulatory defect is limitation of diastolic filling of the ventricles. Common eponyms are Pick's disease and syndrome of Delorme. Lower was the first to describe constrictive pericarditis as a pathologic entity, in 1669. It was not until 1895, however, that Weill predicted surgical cure when he stated, "It will one day come within the province of surgery to deliver the heart from the shell which strangles it." Several years later Delorme, on the basis of careful observations made on cadavers, recommended operative treatment by lysis and excision of the adherent pericardium, but his proposal at that time was not favorably received. Rehn reported the first successful pericardiectomy in 1913. At the time of Churchill's report in 1929, representing the first surgical success in the United States, 37 cases of pericardiectomy had been published. The slow acceptance of pericardiectomy for constrictive pericarditis was, in part, a result of some confusion in the pathologic anatomy and physiology of the lesion. Brauer advocated an operation that consisted of resection of the precordial portions of the ribs and sternum in the belief that the heart was immobilized by fibrous scars attached to the anterior chest wall. Schmieden's report of seven surgically treated patients in 1926 and Churchill's thoughtful analysis of the problem published a few years later firmly established pericardiectomy as the technic of choice.

Pathologic Features. Although tuberculosis can be established pathologically in less than one third of cases, it is considered to be etiologic in the majority, since symptomatic manifestations of the disease follow the stage of typically tuberculous healing when dense fibrous scar tissue with contraction oppresses the heart. Hence, tubercles and the organism itself have frequently long disappeared from the pericardium. Thickening of the pericardium is pronounced and may reach several centimeters. The parietal pericardium most commonly produces the constricting envelope about the heart, although occasionally the epicardium alone may be the restricting factor. Frequently the pericardial space is obliterated. Adhesions between the parietal and the visceral layers of pericardium do not cause significant interference with cardiac action. Such adhesions frequently follow rheumatic fever, which seldom, if ever, produces constrictive pericarditis.

Trauma with resulting hemopericardium and fibrous organization occasionally produces this condition. Constricting pleuritis may develop in a similar fashion with associated constrictive pericarditis. In this com-



Fig. 3. a, posteroanterior and b, lateral roentgenograms in a case of constrictive pericarditis. Calcification in the pericardium is present in more than 50 per cent of cases. It is noteworthy that there is no cardiac enlargement nor evidence of pulmonary congestion.

bination, pulmonary decortication may be as vital to surgical success as pericardiectomy. Other rare causes are cholesterol pericarditis and specific infections with staphylococcus and actinomycosis bovis.

Significant calcification is radiologically obvious in only about 50 per cent of cases, although tomograms will reveal at least slight calcification in most. A solid wall of calcium occasionally surrounds the entire heart, producing a striking roentgenographic picture (Fig. 3).

In chronic cases atrophy of the heart may occur, and it demands early operation. This atrophy is both histologic and gross and is not entirely reversible after pericardiectomy.

Physiologic Alterations. The principal circulatory defect in constrictive pericarditis is limitation in diastolic filling of the ventricles. This results in diminution in stroke volume and usually decreases cardiac output per minute even though compensatory tachycardia may be present. An elevated end diastolic pressure is characteristic, owing to lack of distensibility of the right ventricle. The resulting increase in right atrial pressure produces an increased venous pressure which ranges from 150 to 410 mm. H_2O. It is extremely unusual for a pressure gradient to exist between the superior or inferior vena cava and the right atrium. Accordingly, constriction of the caval orifices producing signs and symptoms of chronic constrictive pericarditis is unusual.

Spontaneous variations in venous pressure, which may be observed, are not usually related to alteration in cardiac output but rather to fluctuations in blood volume. Lyons has shown that intravenous administration of fluids to these patients may elevate venous pressure by 130 to 160 mm. H_2O, while phlebotomy may induce a decrease of 30 to 60 mm. H_2O.

Clinical Manifestations. The diagnosis of chronic constrictive pericarditis should be considered whenever a patient presents a picture suggesting congestive heart failure without the usual causes. Peripheral edema, ascites, hepatomegaly, and increased venous pressure are apparent, but pulmonary congestion, orthopnea, murmurs, and cardiac enlargement remain conspicuously absent. The characteristic features of chronic constrictive pericarditis include: 1. increased venous pressure; 2. edema, ascites, and pleural effusion; 3. quiet heart with normal or reduced blood pressure, normal sounds, and a paradoxical pulse; 4. electrocardiographic changes

including low voltage QRS and alterations of T waves; and 5. roentgenographic evidence of pericardial calcification.

The typical patient is seen in the third decade of life although the ages of patients range from 6 to 60 years. Venous distention with elevated venous pressure is always present. In more than 90 per cent of patients, hepatomegaly, peripheral edema, ascites, and tachycardia are also present. In more than 80 per cent, diminution in heart sounds, decreased blood pressure with paradoxical pulse, and pleural effusion are noted. Exertional dyspnea and cyanosis are common findings. All patients exhibit decreased cardiac pulsation on fluoroscopy. Kymograms show absence of diastolic thrust in the cardiac silhouette. Significant calcification is present in about half of these patients.

Cardiac catheterization is seldom necessary to complete the diagnosis. When performed, the elevated caval pressures equal right atrial pressure with no gradient. Myocardial fibrosis and endocardial fibrosis cannot be differentiated from chronic constrictive pericarditis by catheterization studies. Atrial fibrillation is present in nearly 25 per cent and is usually associated with chronic disease and myocardial atrophy.

Frequent mistaken diagnoses include congestive heart failure, cirrhosis, hepatitis, idiopathic polyserositis, and nephrosis. Congestive failure may be excluded by the findings of dry pulmonary fields and a small, quiet heart without murmurs. Although hepatic function is frequently impaired in patients with constrictive pericarditis, the presence of cervical venous distention should readily distinguish the condition from cirrhosis and hepatitis as well as polyserositis and nephrosis.

Treatment. Pericardiectomy for chronic constrictive pericarditis elicits one of the most dramatic surgical cures in the field of medicine. Diuresis usually begins in the immediate postoperative period. The chronically ill, water-logged patient with an abdomen distended by ascitic fluid usually gains a normal appearance within several weeks.

Digitalis in the preoperative preparation of these patients is usually contraindicated since it may further decrease cardiac output. A period of bed rest, restriction of salt and fluids, a high protein diet, and mercurial diuretics may aid in the attainment of an optimum condition for operation. Paracentesis for massive ascites may simplify anesthetization and pulmonary ventilation in the early postoperative period. The presence of tuberculosis activity in the pericardium indicates drug therapy but should not long defer surgical treatment.

Excellent exposure for decortication of both ventricles may be obtained through a bilateral anterior fourth or fifth interspace incision which transects the sternum (Fig. 4). Previous surgical failures were due in part to inadequate exposure through small left parasternal or interspace incisions. Complete decortication of the ventricles should be the surgical aim; further resection over the atria and intrapericardial portions of the great vessels is not essential and may add to the risk of operation. The left ventricle should be freed first to avoid sudden transference of peripheral congestion to the pulmonary bed. A cleavage plane usually can be developed over the epicardium and carefully advanced with sharp and blunt dissection (Fig. 4). Occasionally it is necessary to remove the epicardium as well. To safeguard the anterior descending branch of the left coronary artery, a small strip of adherent pericardium may be left along the path of this vessel.

Gratifying response to pericardiectomy can be expected in more than 80 per cent of patients. The two most common causes of operative failure are inadequate pericardial resection, and irreversible myocardial fibrosis and atrophy. The increased incidence of auricular fibrillation, myocardial fibrosis and atrophy with long duration of the syndrome of chronic constrictive pericarditis bespeaks the urgency of early diagnosis and surgical treatment.

MITRAL VALVULAR DISEASE

More than fifty years ago Brunton and later Samways suggested that since mitral stenosis was in essence a mechanical obstruction to circulation it should be amenable to surgical relief. In 1923 Cutler and Levine reported the first actual clinical attempts to relieve mitral stenosis by valvulotomy which met with no success. In the next few years others made unsuccessful attempts, and the

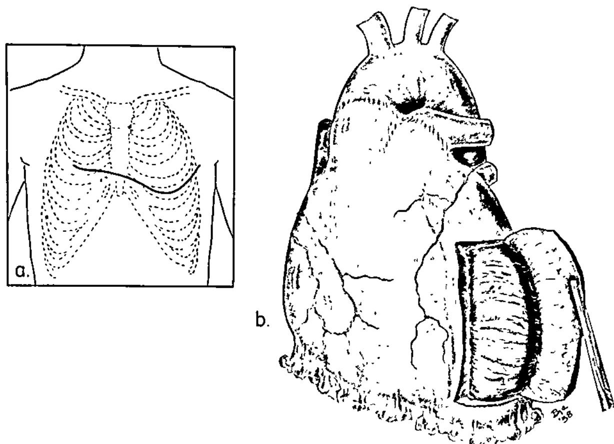


Fig. 4. a, line drawing showing modern incision for pericardiectomy. Such a sternal transecting bilateral interspace incision affords excellent exposure. b, tone drawing illustrating the initial dissection in pericardiectomy. The left ventricle should be freed first to prevent acute pulmonary vascular congestion. Note the bulging myocardium in the resected area.

problem was not attacked clinically again until the efforts of Smith, Bailey, Harken, and Brock soon after World War II. Since that time, surgical treatment of mitral stenosis has been developed and perfected by experience in literally thousands of operations. More recently operations for mitral regurgitation have been proposed and used in a relatively small number of patients with less satisfactory but nevertheless encouraging results.

Acute rheumatic fever and valvulitis is the usual etiologic factor in production of mitral stenosis or mitral incompetence. The initial rheumatic valvulitis occurs along the margin of the leaflets. If the cusps remain separate and only the margins are affected, the final result is permanent thickening and distortion of the edges of the cusps which are of no functional importance. Fusion of the cusps at the commissures of the valve where chordae tendinae insert leads to stenosis of the valve, interfering with mobility of the valve in opening and closing during the cardiac cycle. Thus, fusion and contraction of the chordae tendinae are just as much a part of the pathologic condition known as mitral stenosis as obstruction of the valve orifice. Calcification frequently occurs in rheumatic mitral valvulitis. Little is known definitely, however, why in some patients rheumatic inflammation leads to mitral stenosis while in others mitral regurgitation may be produced. In regurgitant lesions the circumference of the annulus may increase, interfering with apposition of the leaflets during systole. Several causes for mitral incompetence are recognized. Destruction of valve leaflets may result and is common when bacterial endocarditis is superimposed on the rheumatic process. Rupture of chordae tendinae or papillary muscle may occur and produces a serious degree of mitral incompetence, which is often rapidly fatal. It is remarkable, however, how severe the valvular involvement from rheumatic inflamma-

tion may become, with either stenosis or incompetence, before symptoms of congestive failure ensue. If the myocardium is not itself seriously involved, the heart has a remarkable capacity to compensate for involvement of the mitral valve. Such patients in many instances may have relief of symptoms by correction of the valvular dysfunction. On the other hand, rheumatic myocarditis in association with mitral valvulitis may lead to early congestive heart failure and death. In severe rheumatic myocarditis, the left atrium may be greatly distended to aneurysmal proportions. So-called giant atrium is usually associated with some degree of mitral regurgitation. For the purposes of this text the clinical and surgical aspects of mitral stenosis and insufficiency will be considered separately insofar as possible. Obviously patients may have degrees of both, but such complicated problems are outside the scope of this presentation.

MITRAL STENOSIS

So-called "pure" mitral stenosis produces typical symptoms. Dyspnea on exertion is the most prominent feature and is brought on by walking 50 to 100 yards or climbing a flight of stairs. Although fatigue at the end of a day may be described by the patient, this symptom is more commonly the complaint of patients with mitral regurgitation. In such cases, shortness of breath may be extreme and brief episodes of pulmonary edema may occur following exercise. Pulmonary hypertension results from the increased left atrial and pulmonary venous pressure. Pulmonary hypertension may lead to hemoptysis, a symptom characteristic of severe mitral stenosis. Extent of the hemoptysis varies from mild streaking of sputum to frank hemorrhage, sometimes leading to exsanguination or suffocation. Paroxysmal nocturnal dyspnea and orthopnea are also common. In far advanced pulmonary hypertension, functional pulmonic valvular insufficiency occurs. Subsequently, functional tricuspid insufficiency and signs of right ventricular failure ensue. Cyanosis occurs late in the disease and may be caused by a combination of pulmonary congestion, reduced cardiac output, and increased peripheral venous pressure. Peripheral embolism occurs more commonly in patients with mitral stenosis than with mitral insufficiency since in the former lesion severe stasis of blood in the left auricle leads to thrombosis. The clots tend to occur in the auricular appendage. Auricular fibrillation, which is a frequent finding in mitral stenosis, predisposes to auricular thrombosis. Moreover, the fibrillation which leads to frequent rapid changes in ventricular rhythm may dislodge a thrombus. The embolus may travel to the cerebral vessels where it may produce serious neurologic symptoms, hemiplegia, and death. Other vital areas of lodgment may be the aortic bifurcation, visceral vessels, or vessels of the extremities. In most instances, prompt surgical removal of the embolus (embolectomy) is indicated.

Mitral stenosis is characterized by a rumbling diastolic murmur at the apex with a crescendo presystolic murmur. An accentuated pulmonary second sound is audible. A Graham Steell murmur of functional pulmonic insufficiency may also be present. If auricular fibrillation occurs, the presystolic murmur may disappear.

Roentgenographically, a typical configuration of the heart in mitral stenosis shows right ventricular enlargement, dilated pulmonary artery, and left atrial appendage (Fig. 5). The left ventricle and aortic knob are inconspicuous. The left atrium is enlarged and encroaches on the esophagus posteriorly, but the chamber is not typically dilated as occurs in mitral regurgitation. Lungs may show chronic passive congestion and hemosiderosis. The electrocardiogram shows right ventricular and atrial hypertrophy with increased P waves.

Operative Treatment. Technics of operation in use for mitral stenosis all stress the importance of control or prevention of mitral regurgitation after valvulotomy by accurate control of extent and direction of the valvular dissection. In most of the earlier attempts valvulotomy was accomplished blindly, usually by introducing a valvulotome into the left ventricle in order to punch out, sometimes at random, a piece of the stenotic valve. In instances in which this purpose was accomplished, severe and frequently fatal mitral insufficiency was produced. It is now well recognized that valvulotomy must be done by division of only the point of fusion of the

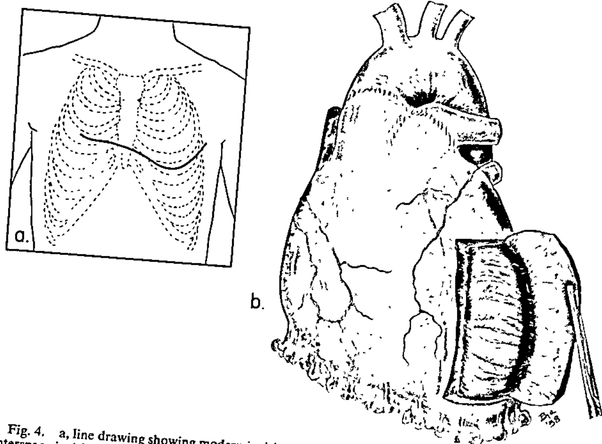


Fig. 4. a, line drawing showing modern incision for pericardiectomy. Such a sternal transecting bilateral interspace incision affords excellent exposure. b, tone drawing illustrating the initial dissection in pericardiectomy. The left ventricle should be freed first to prevent acute pulmonary vascular congestion. Note the bulging myocardium in the resected area.

problem was not attacked clinically again until the efforts of Smith, Bailey, Harken, and Brock soon after World War II. Since that time, surgical treatment of mitral stenosis has been developed and perfected by experience in literally thousands of operations. More recently operations for mitral regurgitation have been proposed and used in a relatively small number of patients with less satisfactory but nevertheless encouraging results.

Acute rheumatic fever and valvulitis is the usual etiologic factor in production of mitral stenosis or mitral incompetence. The initial rheumatic valvulitis occurs along the margin of the leaflets. If the cusps remain separate and only the margins are affected, the final result is permanent thickening and distortion of the edges of the cusps which are of no functional importance. Fusion of the cusps at the commissures of the valve where chordae tendinae insert leads to stenosis of the valve, interfering with mobility of the valve in opening and closing during the cardiac cycle. Thus, fusion and contraction of the chordae tendinae are just as much a part of the pathologic condition known as mitral stenosis as obstruction of the valve orifice. Calcification frequently occurs in rheumatic mitral valvulitis. Little is known definitely, however, why in some patients rheumatic inflammation leads to mitral stenosis while in others mitral regurgitation may be produced. In regurgitant lesions the circumference of the annulus may increase, interfering with apposition of the leaflets during systole. Several causes for mitral incompetence are recognized. Destruction of valve leaflets may result and is common when bacterial endocarditis is superimposed on the rheumatic process. Rupture of chordae tendinae or papillary muscle may occur and produces a serious degree of mitral incompetence, which is often rapidly fatal. It is remarkable, however, how severe the valvular involvement from rheumatic inflamma-

tion may become, with either stenosis or incompetence, before symptoms of congestive failure ensue. If the myocardium is not itself seriously involved, the heart has a remarkable capacity to compensate for involvement of the mitral valve. Such patients in many instances may have relief of symptoms by correction of the valvular dysfunction. On the other hand, rheumatic myocarditis in association with mitral valvulitis may lead to early congestive heart failure and death. In severe rheumatic myocarditis, the left atrium may be greatly distended to aneurysmal proportions. So-called giant atrium is usually associated with some degree of mitral regurgitation. For the purposes of this text the clinical and surgical aspects of mitral stenosis and insufficiency will be considered separately insofar as possible. Obviously patients may have degrees of both, but such complicated problems are outside the scope of this presentation.

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Fig. 5. Roentgenograms of chest in patient with pure mitral stenosis. So-called "mitralized" cardiac configuration consists of right ventricular hypertrophy, prominent pulmonary conus, distended left auricular appendage, and inconspicuous aortic knob. In lateral view, characteristic indentation of the esophagus by dilated left atrium is shown.

Fig. 6. Drawing showing the importance of the anterior mitral leaflet as a baffle in the outflow tract of the left ventricle preventing mitral regurgitation. Preservation of integrity of this leaflet is vital to successful commissurotomy.

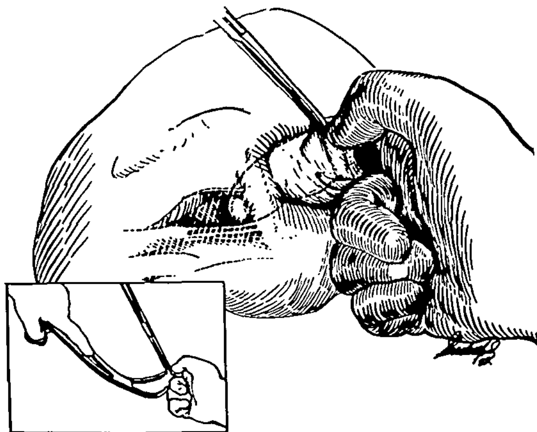


Fig. 7. Drawing showing usual technic of mitral commissurotomy approaching the valve through the left auricular appendage for digital dissection of the fused commissures.

valve leaflets. The anteromedial leaflet is vital to the efficiency of the left ventricle, serving as a baffle to the left ventricular outflow tract assisted to a lesser degree by the posteromedial leaflet in preventing reflux into the left atrium (Fig. 6). In order to protect these leaflets and at the same time increase the size of the orifice, the valvular division is made at the point of fusion of the leaflets known as the *commissures*. By this technic maximum relief of the stenosis is obtained without disturbing the competence of the valve.

Most surgeons approach the valve through the left auricular appendage using a purse-string suture around the base of the appendage for control of hemorrhage. Dissection of fused commissures can often be accomplished by digital manipulation with the right index finger (Fig. 7). In particularly difficult cases the valve must be opened with a cutting instrument, and a wide variety of valvulotomes, scissors, and dilators are available for this purpose.

Prevention of embolization during the procedure is of prime importance, particularly in patients with auricular fibrillation. Atrial thrombosis occurs frequently in patients with mitral stenosis due to stasis of blood in the left atrium. Fibrillation adds to the stagnation of blood in the atrium and peripheral embolism may occur. Prevention of these complications during operation may be difficult, but various steps may be used to reduce the incidence. If the appendage is filled with thrombus, the thrombus may be flushed out of the heart by releasing a gush of blood from the distended atrium. It may be possible to approach the valve through an opening made in a pulmonary vein if necessary and thus avoid disturbance of the clot in the appendage. During intracardiac manipulation temporary occlusion of carotid circulation for periods less than 60 seconds may prevent cerebral embolism. In all instances the patients are examined carefully postoperatively to locate any peripheral embolism. Prompt

embolectomy under these circumstances may be lifesaving.

Recently new technics have been used in patients with mitral stenosis with good results. Bailey has advocated an approach to the valve through a right thoracotomy. In this technic the exploring finger is introduced into the left atrium at a point of junction of the right pulmonary veins with the heart. Actually this approach has proved particularly useful for exposure of the mitral valve for an open repair or valvulotomy. Using the pump oxygenator for temporary cardiopulmonary bypass, the left atrium is opened widely on the right side. The location of the mitral valve is such that an accurate and complete visualization is possible only from this direction. Valvulotomy may be accomplished by incision at the commissures and dilatation under direct vision. This technic is useful in patients with unsatisfactory valvulotomy by the closed technic or when mitral stenosis recurs after previous successful valvulotomy.

MITRAL INSUFFICIENCY

Typical symptoms of mitral regurgitation are somewhat different from those of mitral stenosis. They include fatigue and generalized weakness more than simple exertional dyspnea. Chronic congestive failure may be present, although patients may continue relatively asymptomatic even if the heart and left ventricle are greatly enlarged. Ultimately, signs of right ventricular failure appear, including hepatomegaly, splenomegaly, peripheral edema, and ascites.

Roentgenograms usually show a remarkably enlarged heart with evidence of pulmonary congestion. The left ventricle and atrium are hypertrophied and distended and the left atrium tends to be greatly dilated, causing an extensive displacement of the esophagus posteriorly. Electrocardiograms show predominant left ventricular hypertrophy but also right ventricular.

In spite of intensive interest in surgical treatment of mitral regurgitation, until very recently the results have been unsatisfactory. Attempts to obturate the mitral orifice during systole by baffles, pericardial slings, synthetic prostheses, and other ingenious devices were mostly failures. Attempts to reduce the circumference of the mitral annulus or repair an incompetent commissure by insertion of sutures through the heart or passage of circumferential sutures about the annulus have provided temporary relief in some patients, but the long-term results of all of these procedures will probably be disappointing.

Recently the pump oxygenator for temporary cardiopulmonary bypass has been used for repair of the incompetent mitral valve under direct vision with encouraging results. Exposure of the valve permits accurate placement of sutures to the exact point of regurgitation. This method of valvulorrhaphy provides hope of relief in severely disabled patients. Unfortunately, these technics will probably be unsatisfactory in patients with extensive valvular calcification or ruptured papillary muscle as the cause of the mitral insufficiency.

AORTIC VALVULAR DISEASE

AORTIC STENOSIS

The fundamental defect in aortic stenosis is mechanical obstruction of the outflow tract of the left ventricle. As a consequence of this increased outflow resistance, a high left ventricular pressure is produced proximally and a low aortic pressure distally. This physiologic derangement produces the deleterious combination of increased ventricular work with reduced coronary perfusion pressure. A further physiologic disadvantage to the heart results from the prolonged systolic ejection period since coronary flow takes place principally during the diastolic phase of the cardiac cycle. Finally, the poststenotic jet stream may produce a Venturi or vacuum effect at the coronary ostia, further reducing coronary perfusion.

Even the normal aortic orifice has considerably less cross sectional area than the aorta. In aortic stenosis, as the effective cross sectional area decreases, the resistance to left ventricular expulsion increases, not in a simple linear fashion but by the exponential third or fourth power. Hence, a critical diameter can be reached, beyond which compensation collapses. With such unfavorable factors, it is indeed remarkable that the critical valve opening may be as little as 10 per cent of normal. The fundamental compensatory mechanism in aortic stenosis is con-

centric hypertrophy of the left ventricle without increase in chamber volume.

Appreciation of this delicate physiologic balance in aortic stenosis readily explains the nearly universal clinical impression that the onset of certain signs and symptoms of decompensation indicates a terminal stage of the disease. The frequency of sudden death in these patients is also not difficult to understand, even in those patients who have had no symptomatic manifestations of aortic stenosis. In light of these various considerations, it is possible that the diagnosis of aortic stenosis in itself may become the only necessary indication for operation.

Pathology. CONGENITAL AORTIC STENOSIS. Two types of congenital aortic stenosis occur: aortic valvular stenosis and subaortic stenosis. Valvular stenosis may appear as an inverted cone or megaphone without evidence of commissures or with commissural fusion. One or more valve cusps may be hypoplastic. Although bicuspid aortic valves may occur without stenosis, they are more commonly associated with stenosis. It is difficult to evaluate the incidence of true developmental aortic stenosis as opposed to commissural fusion and valvular derangement due to inflammatory processes early in life.

The valve cusps may be thickened or bulbous, resembling those of the embryo before the definite stage of cusp formation is seen. There may be considerable increase in hyaline connective tissue with scattered mucinous degeneration of loose connective tissue, perhaps representing fetal mesenchymal tissue due to developmental arrest. If the child survives, to reach adulthood, the deformity of congenital valvular stenosis may progress with deposition of platelet thrombi and calcium until the structure is buried in nodular calcified plaques obscuring the original congenital nature. Undoubtedly a significant number of valvular deformities, classified as acquired aortic stenosis, are congenital in their inception.

Subaortic valvular stenosis results from incomplete involution of the embryonic bulbus cordis with persistence of the demarcating fibrous ridge normally occurring at the junction of the bulbus cordis and the original ventricle. The position of this embryologic fibrous ring coincides with the stenotic area observed in most cases.

Coexistent congenital defects associated with aortic stenosis are not unusual. Some of the more frequent concomitant derangements are coarctation, patent ductus, aortic atresia, and endocardial fibroelastosis.

The relative incidence of valvular versus subvalvular congenital aortic stenosis is difficult to assess. In an analysis of 1,000 autopsies of congenital heart disease, Abbott found 11 cases of aortic valvular stenosis and 18 of subaortic stenosis. In the authors' open transaortic operation series, there were seven subvalvular, seven valvular, and one combined. However, an undetermined number of patients with congenital valvular aortic stenosis may be concealed in the acquired group.

ACQUIRED AORTIC STENOSIS. Characteristically acquired aortic stenosis is, in effect, calcific aortic stenosis and is most commonly caused by rheumatic fever. Indeed, in one large clinical series over half the patients had combined aortic and mitral stenosis, thus suggesting the etiologic significance of rheumatic fever. As has been previously pointed out, however, many cases of congenital valvular stenosis lose their identity in the acquired group with the deposition of calcium. In addition, congenital bicuspid valves without stenosis may develop calcific aortic stenosis. Acquired calcific aortic stenosis primarily due to atherosclerosis is probably rare and certainly not as common as previously considered. Although bacterial endocarditis constitutes an ever present threat in both congenital and acquired aortic stenosis, it is a rare cause of stenosis. Primary cardiac tumors have also been reported as rare causes.

The high degree of calcification associated with aortic stenosis compared with stenotic lesions of other valves is believed to be related to abnormal mechanical stresses of the deformed valve in a high pressure area. The extreme degree of grotesque deformity of the aortic valve commonly seen in calcific stenosis cannot be overemphasized and has considerable surgical significance in the technic and results of valvulotomy. It is commonly difficult to demonstrate even vaguely the previous cusps and commissures; and with their gross distortion by calcific verrucae, it is sur-

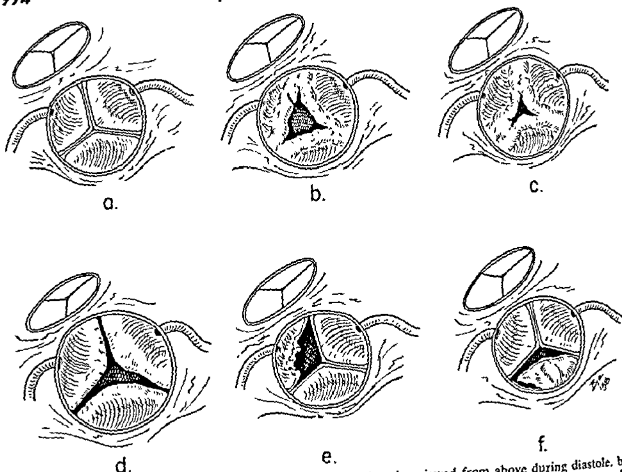


Fig. 8. a, drawing showing appearance of normal aortic valve viewed from above during diastole. b, rheumatic aortic insufficiency with some stenosis. c, rheumatic stenosis with slight insufficiency. In such acquired calcific stenosis the valve cusps are often grotesquely deformed. d, syphilitic aortic insufficiency caused by dilatation of the annulus fibrosus. e, aortic valvular insufficiency caused by bacterial endocarditis. f, aortic valvular insufficiency resulting from a traumatic commissural tear of one leaflet.

prising that any valvular function remains (Figs. 8, 9).

Clinical Considerations. The physiologic changes resulting from acquired aortic stenosis develop long before the onset of symptoms. This frequent dormant period without symptoms has been responsible for the false clinical impression that aortic stenosis is a relatively benign condition. Sudden death is not unusual and may even occur in asymptomatic patients. In general, however, there appears to be a correlation between the severity of symptoms and stenosis. Although tight stenosis does occur without symptoms, eventual subjective evidence of the disease is the rule. The usual progress is late development of exertional dyspnea, fatigability, paroxysmal nocturnal dyspnea, orthopnea, and syncope. Vertigo and syncope result from cerebral anoxia. Angina is usually a late symptom occurring in over 50 per cent of patients and denotes a grave prognosis without surgical intervention.

The physical signs are characteristic. Cardiac enlargement with a forceful apex beat stands in marked contrast to the diminished peripheral pulse. A systolic thrill is palpable over the precordium which radiates into the neck. The harsh systolic murmur can be heard loudest over the right second intercostal space and is well transmitted along the course of the great vessels into the neck. This murmur is often heard posteriorly in the interscapular region. An aortic second sound is usually present, though it may be diminished or absent.

If the systolic murmur is transmitted to the apex, confusion may arise with mitral insufficiency. More troublesome, however, is the frequent occurrence of an Austin Flint murmur caused by transmission of a diastolic murmur to the apex when a degree of relative



Fig. 9. Photograph showing characteristic gross features of calcific aortic stenosis with extensive deformity of valve.

aortic insufficiency coexists. In a significant number of patients with rheumatic aortic stenosis, mitral stenosis may be a combined lesion. The classical rumbling quality with presystolic accentuation usually allows differentiation of the mitral stenotic murmur. Although relative aortic insufficiency is not uncommon in acquired aortic stenosis, the latter is characteristically the predominant derangement. When demonstrable, a plateau pulse suggests aortic stenosis. Blood pressure may be diminished but is often relatively normal.

Congenital aortic stenosis, particularly subaortic, often exists for years before symptoms arise, and the recognition of heart disease may be dependent on routine examination for other reasons. Differentiation of valvular from subvalvular stenosis on the basis of physical findings is extremely difficult, if not impossible. Previous attempts to delineate the two types by the presence of a normal aortic second sound have proven completely unreliable.

Roentgenographic examination of the chest may reveal left ventricular enlargement, but the expansion in the cardiac silhouette is rather subtle, since it is due to concentric hypertrophy without dilatation. The right anterior oblique view best reveals left ventricular enlargement. Poststenotic dilatation of the ascending aorta may be evident and is most marked in the congenital group. Fluoroscopy demonstrates a significant contrast between forceful ventricular systole and relative decrease in aortic pulsation. Demonstrable calcification is rare in children but frequent in adults.

Electrocardiography is particularly useful in aortic stenosis. Usually a pattern of left ventricular hypertrophy is present with left ventricular strain. In rheumatic aortic stenosis, coexistent right axis deviation usually signifies associated mitral stenosis. Electrocardiograms are helpful in appraising cases of congenital aortic stenosis, since symptoms are often difficult to evaluate in children.

When clinical evaluation fails to give a firm

diagnosis, three special studies may be useful, namely, pulse tracings, angiocardiography, and left heart catheterization. In aortic stenosis, a delay in the upstroke of the pulse wave appears, usually interrupted by an anacrotic notch. In the angiocardiogram, the area of poststenotic dilatation may be delineated, differentiating valvular and subvalvular stenosis. Left heart catheterization is a somewhat more formidable procedure than right heart catheterization. Pressure tracings from the left ventricle reveal extremely high pressures with an abrupt reduction as the tip of the catheter passes through the stenotic area. Differentiation between valvular and subvalvular stenosis may be obtained with left heart catheterization.

Surgical Management. Selection of patients for aortic valvulotomy may ultimately become only the problem of diagnosis. It now appears that with the increasing safety allowed by the open transaortic approach, aortic stenosis may be the only necessary indication for operation. At the present time, operation should be deferred in those patients who are asymptomatic, without roentgenographic evidence of cardiac enlargement, and who show no electrocardiographic evidence of significant left ventricular hypertrophy or strain. This is because in both congenital and acquired aortic stenosis a long latent period often persists for 10 or more years. In contrast, a very tight congenital valvular stenosis may be incompatible with early life unless a patent ductus or foramen ovale allows temporary survival. Under these circumstances, valvulotomy may be necessary in the first few days after birth. Certainly the development of cardiac decompensation or atrial fibrillation never should be allowed in patients who are carefully followed, since such deterioration has grave prognostic implications. Once symptoms or signs of left heart strain develop, the period between onset and death is relatively short and averages about one or two years.

Historically two men stand out in their early pioneering efforts to treat aortic stenosis. Tuffier in 1913 performed a successful aortic valvulotomy digitally through the invaginated wall of the aorta itself. The next year Carrell published a paper showing that open transaortic valvular procedures with inflow occlusion were safe, provided the period of circulatory arrest did not exceed 2.5 minutes. It is interesting that Tuffier assisted Carrell in some of these surgical procedures on dogs. Surgical interest then waned until 1947 when Smithy, who was himself a victim of aortic stenosis, revived clinical interest and urged the application of experimental methods to clinical use in the surgical treatment of the diseased valve. Since then a number of different methods and technics have been developed for this purpose, including both closed transventricular and transaortic approaches, as well as the open or direct approach using hypothermia or the artificial heart-lung apparatus. The recent application of cardiopulmonary bypass, using the artificial heart-lung apparatus to the open transaortic approach, has distinct advantages. With a pump oxygenator there is no severe time limitation during the open portion of the procedure. Danger of ventricular fibrillation is lessened, and should it occur, defibrillation is easier.

In the technical performance of aortic valvulotomy the important principle of the limited objective should be followed. This is because only a small increase in cross sectional area suffices to permit relief of the aortic stenosis and because, if strenuous efforts are made to reconstitute an anatomically normal valve opening, there is grave danger of producing intolerable aortic insufficiency. In the case of subvalvular stenosis great care must be exercised to avoid injury to the aortic cusp of the mitral valve, which is in direct relation to one third of the circumference of the stenotic area.

In the immediate period after operation prophylactic antibiotic therapy seems essential because of the frequency of subacute bacterial endocarditis at this time. The results of open transaortic valvulotomy employing cardiopulmonary bypass are now good and will continue to improve as more experience is gained with this direct approach. In our series of 30 cases in which this method of treatment was employed, there were no operative deaths in those with the congenital form of the disease. The operative risk in patients with the acquired form of the disease has been found to be somewhat higher, owing to the related coronary insufficiency.

AORTIC INSUFFICIENCY

Aortic insufficiency constitutes a condition in which blood ejected into the aorta is allowed to regurgitate into the left ventricle because of aortic valvular incompetence. The similarities in the effects of aortic stenosis and aortic insufficiency are noteworthy. Both produce dyspnea, orthopnea, angina, syncope, excessive left ventricular work, decreased net cardiac output, and left sided failure with essentially the same frequency. Also similar are inadequacies of coronary, cerebral, and peripheral circulation. The ominous threat of sudden death is common to both valvular lesions. The hemodynamics in these two lesions are, of course, quite dissimilar.

Reflux of blood into the left ventricle increases ventricular and diastolic pressure. As a direct result, inflow of blood from the left atrium is impeded with consequent pulmonary vascular congestion. Compensation is effected by an increased stroke volume through left ventricular hypertrophy and dilatation. Secondary compensation also results from the elastic reservoir function of the thoracic aorta, which expands markedly during systole and then passively contracts during diastole. In spite of the increased cardiac work demanded, the heart receives diminished coronary perfusion. This is because coronary perfusion takes place principally during diastole and diastolic aortic pressure in open aortic insufficiency is usually very low.

Pathology. William Harvey in 1628 presented the first clear description of valvular function when he wrote, "The several valves of the heart are so arranged that the blood once received into the ventricles shall never regurgitate and once forced into the pulmonary artery and aorta shall not flow back upon the ventricles." The earliest descriptions of aortic insufficiency which appeared many years later by Cowper, Vieussens, Morgagni, and Hodkin were of mixed lesions including both stenosis and insufficiency. Corrigan first presented the clinical picture of pure aortic insufficiency, and subsequently his contemporary, James Hope, proved experimentally the origin of the second heart sound and the murmur of aortic insufficiency. It was also Hope, not Corrigan, who first described the water-hammer pulse.

Effective antibiotic therapy during the past 15 years has produced a significant reduction in the incidence of syphilitic aortic insufficiency. In a recent analysis of 100 cases of aortic insufficiency, the etiology was rheumatic in 83, syphilitic in 12, congenital in 4, and traumatic in 1 (Segal, Harvey, and Hufnagel). In a series of 2,000 cases of rheumatic fever in young people with long term study, the incidence of aortic insufficiency was 6.5 per cent (Bland and Wheeler). The lesion appeared twice as frequently in males. Although aortic stenosis or combined aortic stenosis and insufficiency represent the more characteristic rheumatic affliction of the aortic valve, pure rheumatic aortic insufficiency is not uncommon. Rheumatic fever may produce pure aortic insufficiency in two ways. First, the aortic annulus fibrosus may be stretched so that the valve cusps, even when undamaged, fail to approximate during diastole; or second and more often, rheumatic fever may cause agglutination of the cusps to the aortic wall, and thus produce apparent widening of the commissural spaces simulating dilatation of the annulus. In advanced stages of the disease, the coronary ostia may become enclosed in cystlike spaces.

Syphilis characteristically produces a generalized dilatation of the aortic annulus fibrosus. Widening of the commissures between the valve cusps prevents coaptation during diastole (Fig. 8). The valve cusps may remain relatively normal although atrophy and distortion sometimes occur. Associated syphilitic aneurysms of the aortic arch are quite common.

Varied congenital abnormalities of the aortic valve may be associated with aortic regurgitation. Usually bicuspid deformities exhibit concomitant aortic stenosis. Aortic insufficiency may also result from subacute bacterial endocarditis, which rarely involves a normal aortic valve but frequently attacks congenitally deformed valves or valves altered by the effects of rheumatic fever. Fenestrations of the valvular cusps may be congenital or acquired and may produce valvular incompetence. Aortic insufficiency occasionally develops as a complication in Marfan's syndrome.

Closed trauma can produce rupture of one or more valve cusps or rupture of the sinus of

Valsalva (Fig. 8). Rupture of the sinus of Valsalva usually results from congenital weakness or subacute bacterial endocarditis. A communication may be thus produced between the aorta and the right atrium or ventricle.

Clinical Considerations. Aortic regurgitation creates a distinctive clinical picture. A blowing or musical early diastolic murmur is usually heard over the right second interspace and is transmitted toward the apex of the heart along the left sternal border. The late mid-diastolic murmur heard at the apex, familiarly known as the Austin Flint murmur, may be mistaken for the diastolic murmur of mitral stenosis. A quite variable systolic aortic murmur frequently occurs. The heart is grossly enlarged with downward and outward displacement of the apex beat, which is particularly forceful. The peripheral vascular signs are characteristic and include the violent collapsing or water-hammer pulse, widened pulse pressure with elevated systolic and greatly reduced diastolic pressure, and demonstrable capillary pulse. Fluoroscopy of the chest shows a rocking motion of an enlarged heart and significant systolic expansion of the aorta. The electrocardiogram typically reveals evidence of hypertrophy and left ventricular strain. Ballistocardiographic tracings are diagnostic.

The age at which symptomatic manifestations of aortic insufficiency develop depends largely on the etiology. In rheumatic fever, there is usually a 10-year latent period after significant aortic insufficiency has evolved, and symptoms arise typically in the third or fourth decade. Symptoms in syphilitic cases usually become manifest in the fifth or sixth decade and the progression is more rapid than in those following rheumatic fever. Compensatory mechanisms have less opportunity in traumatic aortic valvular insufficiency and death commonly occurs within a year.

When symptoms do begin, easy fatigability, palpitations, and exertional dyspnea are the first to be noted. Later symptoms are those of congestive failure and angina from coronary insufficiency. Syncope may follow periods of cerebral vascular insufficiency. Sudden death is not uncommon.

Surgical Treatment. Surgical approaches to aortic valvular insufficiency have been circuitous until recently, when the advent of temporary cardiopulmonary bypass made open definitive repair possible. The Hufnagel ball-valve plastic prosthesis offered a degree of improvement to some patients, but because of anatomic and physiologic factors, it was necessary to insert the valve in the descending thoracic aorta and thus the regurgitation was only partially ameliorated (Fig. 10). Complications, such as false aneurysm and embolic phenomenon, were not infrequent. Circumclusion technics have not been very satisfactory because the constricting suture or band frequently cuts through the aorta or rides up on the coronary arteries, producing coronary occlusion. The search for an ideal valvular prosthesis which may be inserted proximal to the ostia of the coronary arteries continues, but many observers doubt that the solution to the problem of aortic insufficiency lies in this approach.

Open plastic repair of the valve during cardiopulmonary bypass with a pump oxygenator appears most promising. The type of repair must of necessity bear technical adaptation to the pathologic deformity. Several principles of repair are now under clinical evaluation. The annulus fibrosus may be incised and its circumferential diameter decreased by suture repair. Portions of the posterior noncoronary area of the proximal aorta can be excised and the aorta repaired, bringing the valve cusps into apposition. Mattress sutures placed in the annulus at the valve commissures have proven successful in some instances. Another approach which has been clinically successful converts the valve into the bicuspid type by suturing two cusps together and then adding cusp area, if needed, by suturing prosthetic pledgets to the cusp edges.

TUMORS OF THE HEART

Neoplasms of the heart are relatively rare, although involvement of the pericardium by malignant tumors arising in adjacent structures is rather common. Among tumors of the heart itself, unfortunately, at least 95 per cent are metastatic. The most common primary tumors producing cardiac metastases include bronchogenic carcinoma, melanoma, lymphosarcoma, and other sarcomas. Direct embolic dissemination through the coronary ar-



Fig. 10. a, photograph of the Hufnagel prosthetic aortic valve in place. The rings which hold the aorta over the valve have inner teeth which prevent ischemic necrosis of the incorporated segment of aorta. b, drawing showing the location of the Hufnagel valve. Since coronary filling takes place during diastole, the valve cannot be placed in the ascending aortic arch. The aortic arch, therefore, remains a regurgitant segment.

teries represents the most common mode of metastasis. Spread to the heart may also occur along lymphatic channels. Usually cardiac metastases are asymptomatic and are brought to light as an interesting post-mortem finding. When symptoms do occur, the diagnosis generally is obvious, but treatment at best consists of palliative radiation. Metastatic cardiac tumors are primarily pathologic curiosities, since the ultimate outcome is not significantly affected by cardiac metastasis but is determined by the primary tumor. Metastatic cardiac tumors most commonly involve the right side of the heart.

In contrast to metastatic tumors, primary tumors of the heart are of real surgical interest. They may be conveniently divided into intracavitary and mural types. Intracavitary tumors are almost exclusively benign myxomas whereas among mural tumors, sarcomas of various cell types predominate.

PRIMARY TUMORS

1. **Intracavitary Type.** From a surgical standpoint it is fortunate that 50 per cent of the primary tumors of the heart are benign myxomas. Since almost all other primary tumors involve the heart essentially as mural growths, myxoma is for practical considerations the principal intracavitary tumor. Characteristically, myxomas arise from the region of the fossa ovalis of the atrial septum on a narrow pedicle. The point of attachment to the septum is generally 1 cm. or less in diameter. The left atrium is involved in about 75 per cent and the right atrium in the remainder. Their size varies from those that are so small as to be asymptomatic, and are diag-

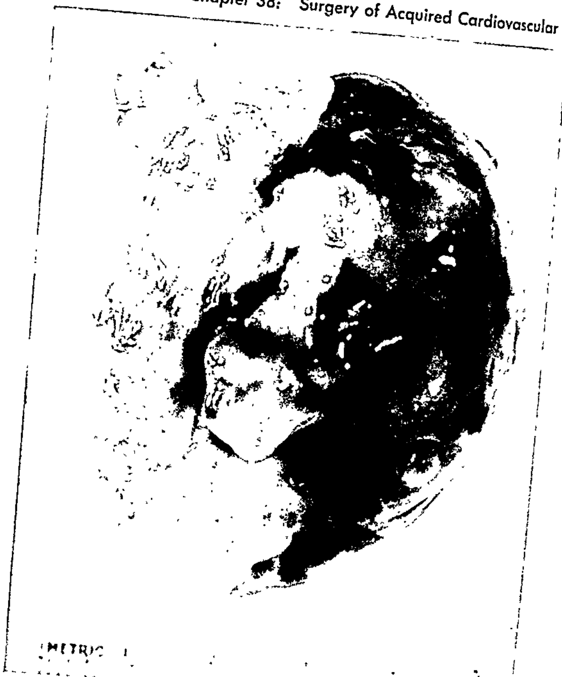


Fig. 11. Photograph of a myxoma removed during cardiopulmonary bypass with open atriotomy. Note the small segment of interauricular septum attached to the short pedicle. Intracavitary myxomas characteristically arise from the interauricular septum near the fossa ovalis.

nosed accidentally, to lesions 6 to 8 cm. in diameter that almost completely fill an already enlarged atrium. Myxomas are now generally conceded to represent a true neoplasm, although formerly some pathologists considered their origin to be from organization of atrial thrombi. Grossly, they may be smooth and round or polypoid and occasionally villous (Fig. 11). Cut surface appearance varies from white and gray to pink and red.

Microscopically, myxomas present a rather poorly cellular stroma containing occasional multinuclear and stellate cells with a thin surface covering of endocardium (Fig. 12). Occasional areas of calcification and hemosiderin deposition may be observed.

The clinical picture of a myxoma arising in the left atrium is similar to that of mitral stenosis with several characteristic and differentiating features resulting from the action



Fig. 12. Photomicrograph (× 200) of myxoma arising in the left atrium from the fossa ovalis. The tumor is covered by endothelium and the loose stroma is mucoid and well vascularized.

of the tumor itself as an obturator (Fig. 13). These important features due to the ball-valve effect of the tumor on the mitral orifice include: (1) dramatic alterations in symptoms and murmurs associated with positional changes; (2) relatively rapid onset with accelerated progression of symptoms; and (3) conspicuously minimal response to medical therapy. A fourth differentiating feature is absence of a history of rheumatic fever.

Tumors arising in the right atrium mimic tricuspid valvular disease or chronic constrictive pericarditis. One unusual case of a patient whom Hanlon successfully treated by cardiopulmonary bypass had an associated atrial septal defect. The patient was intensely cyanotic because of impingement of the tumor on the tricuspid valve, which accentuated the right-to-left shunt.

Catheterization of the heart uniformly shows evidence of obstruction to atrial outflow and increased pulmonary capillary pressure with left atrial tumors. Definite diagnosis of intracavitary myxoma can be obtained in nearly every instance by angiocardiography. An atrial filling defect is demonstrable, and often the point of attachment to the atrial septal wall is clearly visualized. Mural thrombi and tumors, since they tend to be laminar, do not ordinarily produce filling defects. Unfortunately, until physicians become accustomed to excluding myxoma when considering the diagnosis of mitral stenosis, the first hint of the true diagnosis will commonly arise when the commissurotomy finger encounters the tumor.

Successful removal of an intracavitary myxoma offers one of the most gratifying ex-

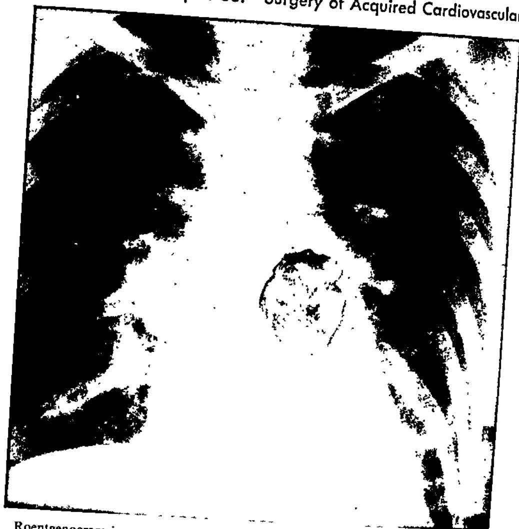


Fig. 13. Roentgenogram in a case of intracavitary myxoma of the left atrium. The x-ray findings are indistinguishable from those of mitral stenosis. The superimposed tumor has a smooth lobulated appearance.

periences in the scope of surgery. Removal through an open atrium during cardiopulmonary bypass using the artificial heart-lung apparatus is a relatively simple technical procedure. Should air embolism into the coronary vessels occur or ventricular fibrillation develop, the pump oxygenator offers a much better means than hypothermia of overcoming this complication. Although we have approached myxomas in the left atrium directly through the left side of the atrial wall, there is reason to believe it may be preferable to use the right sided approach through the right wall of the left atrium or through the septum of the right atrium. Such approaches would minimize the dangers of air embolism incident to open operations on the left side of the heart. Should a myxoma first become evident in the course of an anticipated mitral commissurotomy, it is best to terminate the operation and make plans for open atriotomy employing cardiopulmonary bypass. The literature is replete with reports of unsuccessful impromptu attempts at removal. Because of the frequency of sudden death associated with mitral or tricuspid occlusion or embolization of the tumor, surgical treatment should be instituted as soon as possible.

2. **Mural Type.** The second most common primary cardiac tumor is the sarcoma. Many isolated cases have been reported of various cell types including myxosarcoma, leiomyosarcoma, fibrosarcoma, rhabdomyosarcoma, malignant mesothelioma, lymphosarcoma, and various angiosarcomas. Other less frequent types are benign and include rhabdomyomas, hamartomas, dermoids, teratomas, fibromas, and lipomas. The presenting symp-

toms and signs are protean and are determined largely by the location and type of the lesion. Hemopericardium is common. Alteration of the cardiac silhouette by the tumor may be noted in the roentgenogram or at fluoroscopy. Electrocardiographic alterations may be produced by sterile pericarditis with bloody effusion or may result from conduction changes due to encroachment of the tumor. Although the outlook for curative surgical intervention is hardly as favorable as in benign intracavitary myxomas, even the sarcomas may be amenable to cure. Scannell reported a fibrosarcoma of the right atrium successfully removed as a wedge excision through a closed operative approach. It is even possible, through an open operation with cardiopulmonary bypass, to excise portions of the ventricular wall and repair the myocardial defect with plastic prosthetic material.

PERICARDIAL TUMORS

Pericardial tumors logically should be considered with tumors of the heart because of their clinical and pathologic association. Excluding cysts, primary pericardial tumors are even more uncommon than cardiac neoplasms. In a review of 413 primary neoplasms, Mahaim found 329 of the heart and 84 of the pericardium.

The various cellular types are those that might be anticipated from a structure composed of fibrous connective tissue, blood vessels, lymphatics, fat, and nerves with a covering on both surfaces of mesothelium. Hence, most primary malignant lesions of the pericardium are fibrosarcomas, various angiosarcomas, lymphosarcomas, liposarcomas, neurogenic sarcomas, and mesotheliomas. Malignant mesothelioma represents the most common type and may produce polyarthritis, as has been observed in their pleural counterpart.

The benign tumors follow a similar morphologic pattern. Some of the most commonly encountered varieties include fibroma, hemangioma, lipoma, neurofibroma, dermoid, and teratoma.

The first manifestations of pericardial tumors may be the same as those of pericardial effusion. Frequently, sterile pericarditis is produced and this causes pain in the chest and electrocardiographic alterations. In most instances the effusion is bloody. The accumulation of fluid may greatly enlarge the cardiac silhouette. In such instances, a picture of chronic tamponade may elicit findings consistent with chronic constrictive pericarditis. The latter may also result from a sheath of tumor encasing the heart. When the pericardial effusion is more rapid, cardiac tamponade may represent the first clinical manifestations of the tumor. Pericardial aspiration may prove not only therapeutic but diagnostic when the fluid is submitted for pathologic examination. Frequently benign tumors first become evident on routine roentgenography of the chest.

The success of surgical treatment is determined largely by the extent and type of the tumor. Most benign pericardial tumors can be excised without difficulty. The first such success was reported in 1930 by Keller and Callender when they removed a neurofibroma arising on the pericardial pleura. Twelve years later, Beck removed a cystic intrapericardial teratoma. In the years since these pioneering operations, there have been many successful surgical extirpations of almost every type of benign tumor encountered in the pericardium. In occasional fortuitous circumstances, malignant pericardial tumors may be encountered at an early stage and completely excised.

PERICARDIAL CYSTS

Pericardial cyst is a distinct clinical and pathologic entity. The term should be reserved for those thin walled sacs containing watery fluid. Frequently used synonyms include pericardial celomic cysts, spring-water cysts, and pleurodiaphragmatic cysts. Their thin, translucent walls are lined with flattened mesothelial cells. They vary in size from small masses, which are detected at the time of thoracotomy performed for some other reason, to unilocular cysts containing more than a liter of clear fluid. These cysts appear most commonly at the cardiophrenic angles with a predilection for the right side. Malignant degeneration has never been reported. They are of developmental origin and grow either as embryonic lacunae that fail to coalesce with the pericardium or as pinched-off rem-

nants of diverticulumlike structures that normally appear in the development of the pericardium.

Pericardial cysts rarely produce symptoms and are generally first revealed on routine roentgenography of the chest. They are ordinarily found forming a bulge on the cardiac silhouette, usually in one cardiophrenic angle. On fluoroscopy, the contour of these cysts may change with movement of the heart or the patient.

Treatment consists in excision. The basis for thoracotomy is the same as for exploration of any intrathoracic mass. Usually the cyst can be readily dissected from the pericardium without rupture.

CORONARY ARTERY DISEASE

More than a half century has elapsed since the first surgical attack in the form of sympathectomy was made by Jonnesco in a case of angina pectoris. During this period and particularly in recent years, intensive experimental and clinical investigations have been directed toward this problem, and while these studies have enriched the literature and have added to greater knowledge and better understanding of the various aspects of coronary artery disease, the surgical approach remains inconclusive and controversial. There are several reasons for this disputed and uncertain status of the surgical treatment of coronary artery disease. For one thing, the natural course of the disease may be highly variable in different patients and even in the same patient at different periods and may be greatly influenced by many factors both intrinsic and extrinsic as well as by medical therapy. For another, precise and accurate evaluation of the clinical results of surgical therapy has been extremely difficult owing to the many variables involved and the inability to provide a properly controlled study.

The underlying pathologic lesion in coronary artery disease is atherosclerosis, which ultimately leads to narrowing and occlusion of the lumen by progressive intimal thickening, intimal hemorrhage, or superimposed thrombosis. As a consequence of this pathologic process, coronary arterial circulation is reduced to a variable degree, depending upon the extent and nature of the lesion and the extent to which intercoronary collateral vessel formation takes place. Serious disturbances occur when the latter compensatory mechanism fails to meet the ischemic effects of the former process of coronary artery occlusion, thus producing one or more of the following effects: 1. angina pectoris; 2. myocardial infarction and damage, fibrosis, congestive failure, aneurysm formation, or rupture; and 3. mechanism failure. Ultimately these disturbances lead to a variable degree of disability, invalidism, and death.

Surgical treatment of coronary artery disease is directed toward relief of these adverse effects of coronary artery insufficiency. The various methods which have been advocated for this purpose may be classified as follows: 1. denervation of the heart for the relief of angina pectoris; 2. improvement of arterial circulation to the myocardium; and 3. decreasing metabolic demands on coronary circulation by thyroidectomy.

Historically, interruption of cardiosensory and motor pathways represents the first method of surgical attack upon coronary artery disease, the procedure having been suggested originally by François Franck in 1899 and successfully performed by Jonnesco in 1916. Since then extensive experimental and clinical investigations have provided a better understanding of the underlying anatomic and physiologic principles of this method of attack. It has been shown that the sensory nerve endings of the heart and aorta are present in the heart muscle, endocardium, and epicardium and in the adventitia of the coronary arteries. The neurons to these sensory endings converge in the periarterial plexus of the coronary arteries, traverse the superficial and deep cardiac plexuses, and course in the middle and inferior cardiac nerves which join the corresponding cervical ganglia of the sympathetic chain. Practically all of these outbound fibers then descend to the upper thoracic ganglia and finally reach their cells in the spinal ganglia by passing through the white rami communicantes into the central portions of the first thoracic and upper four or five intercostal nerves. The vasomotor efferent or accelerator impulses to the heart and coronary arteries differ from the sensory, and their actions and pathways are not as well understood. These pathways involve both vagal and sympathetic nerves.

but the exact mechanism of their action in producing vasoconstriction and vasodilation has been difficult to determine.

In general, three methods of denervation of the heart have been employed clinically. These include: 1. cervicothoracic ganglionectomy; 2. posterior rhizotomy; and 3. paravertebral chemical (alcohol) block of the upper four or five sympathetic ganglia. The advantage of the first two procedures lies in the fact that they provide a more accurate and permanent interruption of cardiosensory nerves, but they have the disadvantage of requiring a major operation and accordingly are associated with a higher operative mortality, about 8 to 10 per cent. Good results in terms of relief of pain, increase of work capacity, and improvement of general condition have been reported in about 70 to 75 per cent of cases following all these methods, but there is no good evidence that survival expectancy is increased.

The procedure of total thyroidectomy for the treatment of coronary insufficiency is now of historical interest only, since this objective may be accomplished by the use of radioactive iodine and possesses the obvious advantage of being associated with much less risk to the patient. The induction of hypothyroidism in euthyroid patients by means of radioactive iodine has now been employed in a large number of patients with severe and intractable angina pectoris, and good results have been reported in about 75 per cent of cases. Final evaluation of this method of therapy in terms of work capacity and longevity remains to be determined.

The various surgical methods directed toward improvement of the circulation of the myocardium may be classified into two broad categories, namely, direct and indirect approaches. The former is aimed at increasing arterial inflow through the coronary arteries by removal of the stenotic lesion or by anastomosis of a systemic artery to the coronary arteries distal to the occlusion. The latter is designed to increase extrinsic coronary collateral circulation by one of several methods, including the grafting of various vascular structures (such as the pericardium, omentum, pectoral muscle, intercostal muscle, lung, and intestines) to the myocardium, implantation of a systemic artery (such as the internal mammary artery) into the wall of the ventricle, ligation of the coronary sinus, and ligation of the internal mammary artery.

Extensive experimental, physiologic, and morphologic studies have been done in an effort to assess the value of these procedures. In general, the experimental designs of most of these studies have employed one or more of the following criteria of benefit: 1. reduction in the amount of myocardial damage or in mortality rate in the group of animals having the experimental "protective" operation as compared with the controls following occlusion of a test artery, such as ligation of the left anterior descending coronary artery; 2. increase in retrograde coronary backflow in the experimentally treated animals as compared with the controls; and 3. gross and histologic evidence of new vessel formation following the experimental procedure.

Many of these procedures have been applied clinically with reports of successful results according to the advocates of the various types of operations. For the most part these results have been evaluated on the basis of symptomatic improvement and increased work or exercise capacity, using the patient as his own control. The operative mortality for the simpler procedures has been relatively low, about 3 to 6 per cent.

Efforts to assess the relative value of these various methods of surgical treatment of coronary artery disease are fraught with many difficulties. The remarkable similarity in the clinical results following these widely varying surgical methods and approaches, as reported by their respective advocates, is particularly striking. This would suggest that they all possess some common factor or mechanism other than improvement in coronary circulation. The major difficulty in their critical evaluation lies in the lack of properly controlled clinical investigations. Until these provisions are made and rigid criteria of benefit are employed, their value will remain controversial. There is sufficient reason to believe, however, that further investigations along these lines, directed toward surgical relief of coronary obstruction, are fully justified.

ANEURYSMS OF THE AORTA

The term, aneurysm, derived from the Greek word "aneurynein" meaning "to widen

or dilate," signifies a hollow tumor or sac directly connected with the lumen of an artery and filled with liquid or coagulated blood or both. Aneurysms may be classified in several ways according to the nature and cause of the lesion. Pathologically, for example, they may be divided into two types: the true aneurysm, in which one or all of the mural layers of the parent artery enter into the composition of the sac; and the false aneurysm, in which the sac is formed by perivascular connective tissue usually following the development of a pulsating hematoma as a result of disruption of the wall of the artery by trauma or infection. Morphologically, they may be divided into three types: sacciform, fusiform, and dissecting. The sacciform aneurysm, as the name implies, has a pouchlike appearance with a relatively narrow neck constituting the orifice from the side of the parent artery to which the larger sac is connected (Figs. 14, 22). Fusiform aneurysms tend to be more spindle-shaped and to involve the entire circumference of the parent artery (Figs. 14, 24, 28). Dissecting aneurysms are of intramural origin and, owing to their distinctive features, are discussed separately. Aneurysms may also be classified according to their cause into congenital and acquired types. The former are relatively uncommon and usually are associated with other congenital anomalies, such as patent ductus arteriosus and coarctation. The latter, by far the more common, are due to arteriosclerosis, trauma, or infection.

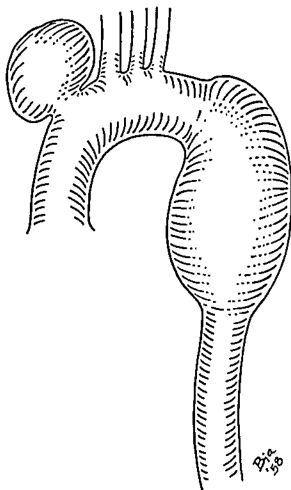


Fig. 14. Diagrammatic drawing illustrating sacciform type of aneurysm arising from ascending aorta and fusiform type of aneurysm involving descending thoracic aorta.

The relative frequency of aneurysms of the aorta has been variously reported according to statistics derived from hospital admissions and necropsy studies. Earlier reports suggested figures ranging from 1 to 2 per cent of all autopsies, but more recent studies indicate that this incidence is somewhat higher. At the Charity Hospital in New Orleans, Matas found that among 81,242 admissions there were 106 aortic aneurysms, an incidence of 0.13 per cent. Earlier reports also indicate a much greater frequency of thoracic than of abdominal aneurysm, the ratio being about 3:1 or 4:1. More recently, however, there is reason to believe that this incidence is changing, probably as a result of the diminishing occurrence of syphilis, which is a common cause of aneurysms of the thoracic aorta. This is well illustrated by the recent studies of Maniglia and Gregory, who found that the ratio of arteriosclerotic to syphilitic aneurysms has increased from 1:8 during the period 1906 to 1931 to 2.5:1 during the period 1949 to 1951. These observations gain further support from our own experience with resected cases of aneurysm of the aorta. In this series of over 650 cases, the thoracic aorta was involved in only about 23 per cent while the remainder were located in the abdominal aorta. Moreover, in the former group, syphilis was considered to be the causative factor in only about half the cases and arteriosclerosis in about one third, whereas among the greater number of aneurysms of the abdominal aorta, arteriosclerosis was the predominant etiologic agent, its incidence being about 96 per cent. It is thus apparent

that in resected cases, at least, arteriosclerosis is now the primary and major cause of aortic aneurysms.

The disease occurs most commonly in the fifth, sixth, and seventh decades of life and predominantly in males. The ratio of males to females in our experience is about 9:1.

Pathogenesis and Pathology. The essential factor in the pathogenesis of aneurysms is damage to the medial elastic coat of the vessel, only the outer adventitious layer remaining to withstand the repeated force of systolic impact. Once this medial disruptive process has occurred, whether it results from trauma, infection, or atherosclerosis, progressive dilatation ensues at the weakened area and pressure is exerted on surrounding tissues. Nature's efforts to counteract this pathologic process apparently take two directions. One consists in development of fibrous tissue presumably produced by chronic irritative hyperplasia in the perianeurysmal tissues. The other consists in deposition of laminas of thrombi on the inner surface of the aneurysm in an effort to maintain normal size of the lumen. Both of these processes, along with extrinsic support from adjacent structures, tend to retard progress of the lesion. In most



Fig. 15. Lateral roentgenogram of patient with syphilitic fusiform aneurysm of descending thoracic aorta showing erosion of vertebrae.

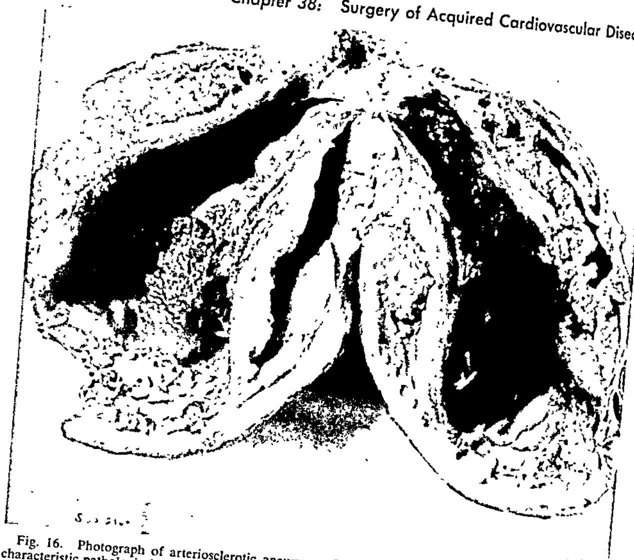


Fig. 16. Photograph of arteriosclerotic aneurysm of abdominal aorta after sagittal section showing characteristic pathologic features including particularly evidence of liquefaction necrosis in laminated clot around lumen.

instances, however, these efforts are unable to cope with the continuous pounding effect of the systolic force so strikingly exemplified in some aneurysms, particularly those of syphilitic origin, by the gradual erosion of adjacent osseous structures (Fig. 15). For one thing, fibrous tissue is an inadequate replacement of elastic tissue for this purpose, progressively becoming thinner and weaker in the face of the unrelenting force of the systolic pressure. For another, the normal process of organization does not usually occur in the laminated thrombus within the aneurysmal sac. Instead, ischemic liquefaction necrosis takes place, usually in the more peripheral portions of the clot immediately adjacent to the outer fibrous tissue wall (Fig. 16). These two factors combine to produce further weakness of the aneurysmal sac, resulting in progressive enlargement and leading ultimately to rupture of the aneurysm. Depending upon the type and location of the lesion, rupture may occur into the mediastinum, pleural, pericardial, or peritoneal cavities, retroperitoneal area, or into adjacent viscera, such as the esophagus, bronchus, gastrointestinal tract, and vena cava.

Although the underlying pathogenic factor, i.e., destruction of the aortica elastica, is the same for most aortic aneurysms, there are certain characteristic anatomic and pathologic features depending upon the nature, location, and cause of the aneurysm. Those of syphilitic origin, for example, tend to involve the thoracic aorta, particularly about the arch, and to be sacciform in character (Fig. 22). Less often, the syphilitic process may be more diffuse with the production of a fusi-

form aneurysm. Arteriosclerosis may also lead to aneurysmal formation in the thoracic aorta, but these lesions are more likely to produce diffuse dilatations of the aorta rather than sacciform aneurysms and to be located in the descending thoracic aorta (Figs. 24, 28). Of interest in this connection is the fact that, whereas in the past aneurysms of the thoracic aorta were considered to be predominantly of syphilitic origin, there are reasons to believe that in recent years this incidence is diminishing with increasing frequency of arteriosclerosis as the cause of these aneurysms. Analysis of our experience with approximately 150 cases of aneurysms of the thoracic aorta treated by resection reveals the incidence of these different types to be as follows: somewhat less than half the cases were of syphilitic origin; about 35 per cent were arteriosclerotic; about 7 per cent were traumatic; and the remainder were congenital, mycotic, or of undetermined origin.

Aneurysms involving the abdominal aorta are predominantly of arteriosclerotic origin. In our own series of approximately 500 cases, arteriosclerosis was considered to be the underlying cause in about 95 per cent. Characteristically, these aneurysms are fusiform, arise just below the origin of the renal arteries, and usually extend distally to involve the bifurcation (Fig. 17). Gross and microscopic evidence of the characteristic arteriosclerotic degenerative mural process is readily demonstrable on section (Fig. 16). Calcific and atheromatous changes are present in the dilated peripheral wall with a laminated thrombus on the inner surface. Immediately adjacent to the peripheral wall of the aneurysm, the laminated thrombus gradually undergoes liquefaction necrosis (Fig. 16). This is considered an important factor contributing to eventual rupture of the aneurysm.



Fig. 17. Photograph made at operation showing characteristic fusiform appearance of arteriosclerotic aneurysm of abdominal aorta arising just below renal arteries and extending down to bifurcation.

Clinical Manifestations. The signs and symptoms of aneurysms of the aorta usually result from encroachment upon adjacent structures. Accordingly, these manifestations depend largely upon the type, location, and size of the lesion. In its early stages, an aneurysm of the thoracic aorta may be asymptomatic or associated with only slight discomfort. In some instances, it may attain full development without causing significant subjective symptoms until the acute episode of fatal rupture occurs. In most cases, however, clinical manifestations reflecting progressive encroachment upon adjacent structures become apparent. Thus, compression of the vena cava and innominate veins by aneurysms of the ascending aorta and arch produces venous distention and edema of the shoulders, head, and neck. Dyspnea and cough result from compression of the air passages, and death by suffocation is not uncommon. Blood streaked sputum is an ominous sign that rupture of the aneurysm into the trachea and bronchus is imminent. Hoarseness may be produced by traction or stretching of the recurrent laryngeal nerve as it passes around a large aneurysm of the aortic arch. Sacciform aneurysms arising an-

Fig. 18. Roentgenogram of chest of patient showing large shadow projecting into right lung field which proved to be a large sacciform aneurysm arising from ascending aorta as depicted in diagram on right.

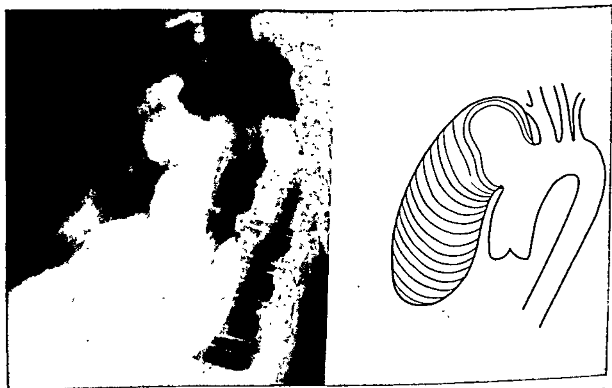


Fig. 19. Angiocardiogram made in same patient as in Figure 18, demonstrating sacciform aneurysm arising from ascending aorta. As depicted in the diagram on the right most of the lumen of the aneurysm is filled with thrombus, thus restricting apparent size of lumen as indicated by the radiopaque dye. This patient was successfully treated by resection of the aneurysm and repair by aortorrhaphy as shown in Figure 32.

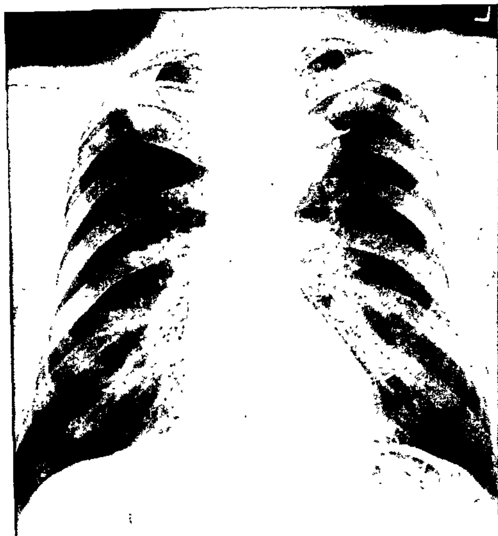


Fig. 20. Roentgenogram of chest showing rounded shadow in upper left mediastinum representing sacciform aneurysm of distal part of aortic arch, believed to be of syphilitic origin.

teriorly from the ascending aorta or transverse arch may progress to produce erosion of the sternum and ribs with the appearance of a pulsatile tumefaction on the anterior thoracic wall. Later, the skin overlying such a mass may become inflamed and may even ulcerate. Aneurysms in the distal portion of the aortic arch and descending thoracic aorta, particularly those of syphilitic origin, may produce erosion of vertebrae and ribs posteriorly (Fig. 15). Under these circumstances, pain may be radicular and excruciating. Cardiac decompensation is usually associated with a diffuse aneurysm of the ascending aorta that produces aortic valvular incompetence.

Diagnosis. The diagnosis of an aneurysm of the thoracic aorta may be suggested by the clinical manifestations described in the preceding paragraph along with roentgenographic demonstration of a pulsating mediastinal mass (Figs. 18, 20, 23, 26). In many instances, however, differentiation from a solid tumor may be difficult because transmitted pulsations from the contracting ventricles may give an appearance of expansion of the lesion, or the presence of a thrombus in the sac may restrict intrinsic pulsation (Figs. 18, 19, 20, 23). Aortography provides the best means of diagnosis since it permits visualization of the aorta and can establish the diagnosis of an aneurysm by the demon-



Fig. 21. Angiocardiogram of same patient as in Figure 20, showing precise location and intraluminal dimensions of sacciform aneurysm.

stration of contrast medium in the sac (Figs. 19, 21, 23, 27).

Aneurysms of the abdominal aorta may be associated with few or no clinical manifestations in their early stages and may remain silent until the acute episode of rupture takes place. Generally, however, they are characterized by a pulsating mass in the abdomen accompanied by varying degrees of discomfort. Later, the patient may experience pain in the upper part of the abdomen or lower portion of the back with extension into the groin or lower extremities. Pain is a particularly important and sometimes ominous sign, for it often represents rapid, progressive enlargement of the aneurysm and may signify imminent or even actual rupture of the aneurysm with retroperitoneal extravasation of blood. The most common and important physical finding is the presence of an expansile pulsating mass, which usually arises at or above the level of the umbilicus and may extend well below this level into the pelvis. The mass may be movable and nontender, but with rapid enlargement and imminent perforation it tends to become fixed and tender.

The diagnosis of an aneurysm of the abdominal aorta is usually not difficult since the presence of an expansile pulsating abdominal tumor may be considered pathognomonic. It can usually be confirmed by roentgenographic studies. Although the diagnosis may be established by lumbar aortography, experience has shown that this is usually unnessary. In the majority of cases

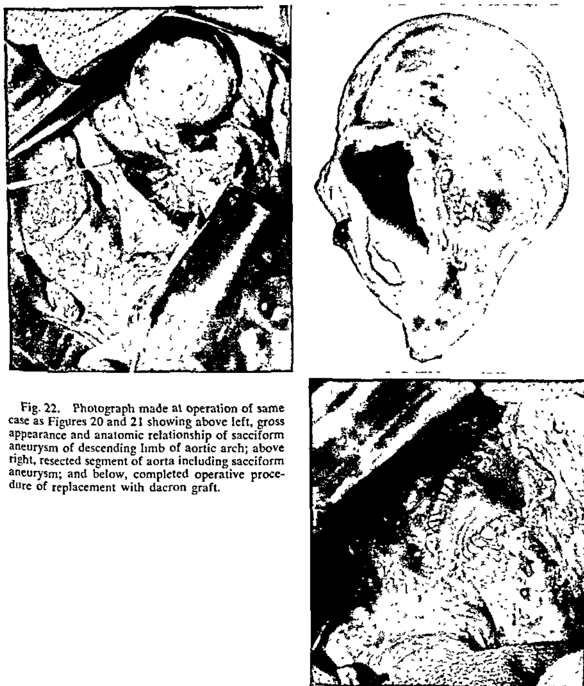


Fig. 22. Photograph made at operation of same case as Figures 20 and 21 showing above left, gross appearance and anatomic relationship of sacciform aneurysm of descending limb of aortic arch; above right, resected segment of aorta including sacciform aneurysm; and below, completed operative procedure of replacement with dacron graft.



Fig. 23. Roentgenographic demonstration of fusiform aneurysm of upper portion of descending thoracic aorta considered to be of traumatic origin. a, posteroanterior roentgenogram showing rounded mediastinal shadow, left border of which is outlined by calcium deposits in outer wall. The esophagus which is outlined by swallowed barium is displaced to the right by the aneurysm. b, angiocardiogram showing precise location and extent of fusiform aneurysm.

Fig 24. Photograph made at operation in same case as Figure 23 showing characteristic gross appearance of fusiform aneurysm of descending thoracic aorta following its mobilization from surrounding structures. Umbilical tape encircles aorta above (to the right) and below aneurysm.

Fig. 25. Photograph made at operation in same case as Figures 23 and 24, showing completed replacement of resected segment of aorta and aneurysm with dacron graft.

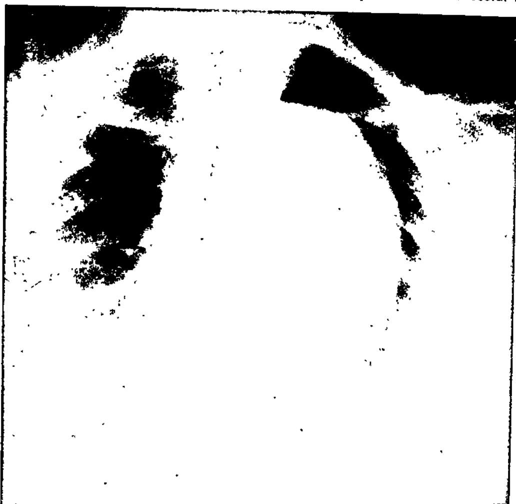


Fig. 26. Roentgenographic demonstration of huge fusiform aneurysm involving most of descending thoracic aorta considered to be arteriosclerotic in origin.

it is possible to demonstrate the presence of the aneurysm in ordinary plain roentgenograms of the abdomen, particularly in the lateral or oblique projections, owing to calcification in its wall (Fig. 30).

Prognosis. Studies on the natural course of the disease have demonstrated conclusively that an aortic aneurysm is a grave disease producing, in most instances, disabling symptoms and ultimate death by rupture and hemorrhage. From an analysis of a series of 1,113 patients with aneurysm of the thoracic aorta, for example, Kampmeier concluded that the average expected duration of life after the onset of symptoms was six to eight months, varying somewhat with the level of involvement. Admittedly, an occasional striking exception will occur, as exemplified by Kampmeier's report of two patients surviving 14 and 15 years, respectively. Although the average duration of life in aneurysms of the abdominal aorta is somewhat longer, the prognosis in this disease is also grave. Estes, for example, in his analysis of 101 patients with this condition, estimated that only 10 per cent of the patients aged 65 years would survive eight years, whereas 65 per cent of normal persons of this age would have a life expectancy of this duration. He also found that within a year after the diagnosis was made, one third of them were dead; one half had died within three years; and more than three fourths had died within five years, usually from rupture. Moreover, the degree of symptoms had no relationship to prognosis, since the patients who were asymptomatic at the time of diagnosis lived no longer than those who had symptoms. Others have reported a similar or even worse prognosis. Wright, for example, in his follow-up study of 68 cases found that only about 4 per cent of the patients had survived five years. Thus, the pres-



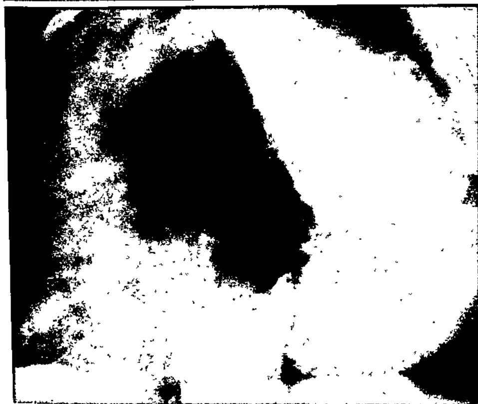


Fig. 27. Angiocardiogram in same case as shown in Figure 26 showing above, aneurysm arising just distal to the left subclavian artery; and below, extending down to involve distal portion of descending thoracic aorta. Note marked elongation and kinking of aorta produced by aneurysm.



Fig. 28. Photograph of specimen removed at operation in same case as in Figures 26 and 27 showing a, gross appearance of large elongated fusiform aneurysm of arteriosclerotic origin. The specimen is shown in two parts owing to the fact that its removal at operation was facilitated by dividing it in this manner; b, sagittal view showing characteristic atherosclerotic mural changes with intimal proliferative degeneration and intraluminary thrombus undergoing liquefaction necrosis.

Fig. 29. Photograph made at operation in same case as Figures 26-28 showing completed replacement of segment of aorta and aneurysm involving virtually the entire descending thoracic aorta with dacron graft. (Proximal anastomosis is to right.)



Fig. 30. Plain roentgenogram of abdomen showing in both posteroanterior and lateral projections fusiform aneurysm of abdominal aorta, the border of which is outlined by calcium deposits.

ence of an aortic aneurysm, regardless of type or location, is a serious and constant menace to the patient and demands prompt treatment.

Treatment. In the past, treatment of aneurysm of the aorta was directed toward obliteration of the aneurysm by inducing thrombosis within the lesion or by reinforcing the wall to forestall perforation. Such procedures proved to be inadequate and may now be considered obsolete. The only effective treatment consists in extirpation of the aneurysm with restoration of normal aortic continuity and function. This may be accomplished by one of several methods depending upon the type and location of the lesion. In sacciform aneurysms, for example, it is usually possible to apply an occluding clamp across the relatively narrow neck of the lesion and in this way to perform tangential excision of the aneurysm with repair by lateral aortorrhaphy (Fig. 32). In fusiform aneurysms, the entire segment of aorta involved by the aneurysm must be removed and replaced by an aortic graft (Figs. 25, 29, 31, 34). For this reason, temporary arrest of circulation through this segment of aorta by the application of occluding clamps immediately above and below the aneurysm is necessary during performance of the procedure. Under these circumstances, and depending upon the level of occlusion, serious consequences may ensue because of the cardiac strain produced and because of the possible ischemic effect upon tissues located distal to the occlusion. In general, the higher the level of occlusion and the longer the period of interruption of aortic circulation, the greater is the risk from such disturbances, particularly for aneurysms arising above the level of the renal arteries, since below this level temporary interruption of aortic circulation is well tolerated. To overcome this problem, one of several approaches may be employed, depending upon the nature and location of the lesion, including hypothermia, temporary shunts, extracorporeal



Fig. 31. Photograph made at operation following resection of aneurysm of abdominal aorta and showing functioning dacron bifurcation graft used to replace excised segment of aorta. The aneurysm in this case arose somewhat higher than usual to involve left renal artery, but circulation to left kidney was restored by end-to-side anastomosis of left renal artery to dacron graft.

circulation, and performance of the procedure in a manner to minimize the period of circulatory arrest (Fig. 33). Replacement of the excised segment of the aorta may be done with the use of an aortic homograft or a suitable substitute of plastic materials, such as nylon or dacron woven tubes. In recent years, our experience has led us to believe that the flexible, knitted, seamless dacron tube is the most satisfactory vascular replacement for this purpose.

Results of these methods of extirpational therapy in our experience with approximately 650 cases of aneurysms of the aorta have been most gratifying and support the conviction that it provides the most effective form of management for this disease. Moreover, there are few contraindications to application of this method of treatment. So long as the proximal portion of the ascending aorta is uninvolved, excision of the lesion is feasible, regardless of its location. The most important contraindications to operations are concerned with serious associated systemic disease, such as severe or disabling cardiac, renal, or cerebral disturbances.

The operative mortality varies with the type and location of the lesion and is particularly influenced by certain factors, such as advancing age, pre-existing heart disease, and acute rupture of the aneurysm. Aneurysms of the thoracic aorta, for example, are associated with a higher operative fatality rate than those of the abdominal aorta, the respective figures being on the order of 25 to 30 per cent and 5 to 10 per cent. The influence of age is shown by the fact that the fatality rate in patients in the eighth decade of life is more than twice that of patients in the fourth and fifth decades. Similarly, the fatality rate in patients with pre-existing heart disease was more than three times greater than that in patients without heart disease. One of the most important factors contributing to operative deaths is acute rupture of the aneurysm. This is well demonstrated by the fact that operative mortality in our series of aneurysms of the abdominal aorta was more than four times greater in the group with rupture than in those with nonperforated aneurysm, the respective figures being about 33 per cent and 7 per cent. There is reason to believe that improvement in the surgical management of these patients, as well as in the actual technical performance of the operation derived from increasing experience, should permit further reduction in the risk. This is well exemplified by the progressive decrease in the operative fatality rate of approximately 20 per cent in our first 100 cases of aneurysms of the abdominal aorta to

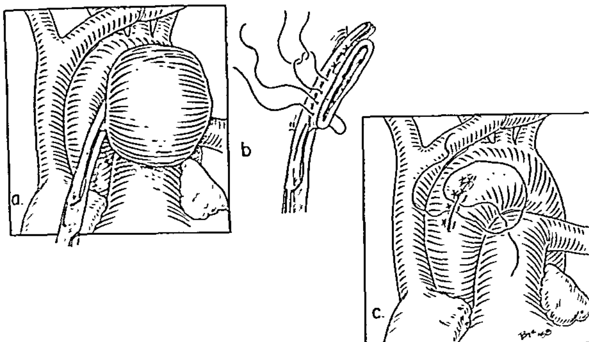


Fig. 32. Drawing showing method of resection of sacciform aneurysm of aorta. a, occluding clamp is applied to neck of sac; b, aneurysm is removed and neck of sac closed by interrupted mattress sutures; and c, aortorrhaphy is completed with second layer of figure-of-eight sutures and occluding clamp released.

4 per cent in our last 100 cases. Finally, studies of long term results of operation with follow-up observations extending over a period of five years reveal a significant increase in life expectancy.

DISSECTING ANEURYSM OF THE AORTA

Dissecting aneurysm of the aorta is a distinct clinical and pathologic entity characterized by hemorrhagic intramural separation of the aortic wall in the region of the media usually communicating with the normal lumen by an intimal tear. Its incidence has been variously reported between 0.1 and 1 per cent of necropsy cases, but with recent increasing awareness of the condition, there is reason to believe that the actual incidence may be higher than that generally reported. Males are affected about twice as often as females with the highest age incidence in the fourth to seventh decades.

The etiology of the disease remains obscure, although certain factors have been considered to have a causal relationship owing to their frequent association with its occurrence. These include arachnodactyly or Marfan's syndrome, pregnancy, hypertension, coarctation, and idiopathic kyphoscoliosis. The possibility of a toxic factor or a specific protein deficiency has also been suggested from certain experimental studies showing the occurrence of aortic dissection and rupture in rats fed sweet-pea meal or aminonitriles.

Pathogenesis and Pathology. The underlying predominant lesion appears to be degeneration *of the elements of the media*, whether it is to be considered a form of the classic "medionecrosis cystica" of Erdheim or of "faults" of Shennan. It is apparently unrelated to atherosclerosis or syphilis. The pathogenesis of the initial rupture or tear in the intima and media is not well understood. According to the prevailing hypothesis the lesion develops as an intramural hematoma from rupture of the thin-walled vasa vasorum within an area of focal medionecrosis with secondary rupture of the intima. Some observers, however, are inclined to the belief that certain mechanical factors may play a role in this process, including conversion of the longitudinal force during diastole into a transverse force with lateral stretching and

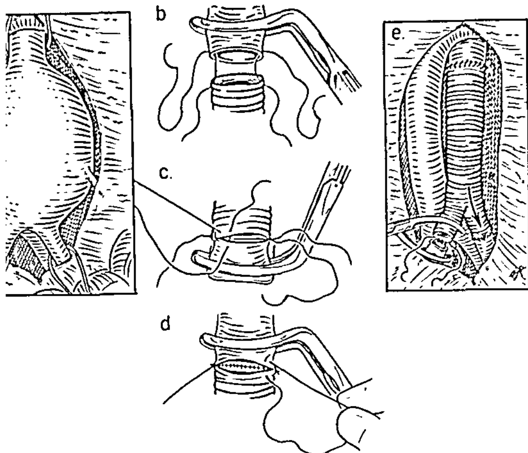


Fig. 31. Photograph made at operation following resection of aneurysm of abdominal aorta and showing functioning dacron bifurcation graft used to replace excised segment of aorta. The aneurysm in this case arose somewhat higher than usual to involve left renal artery, but circulation to left kidney was restored by end-to-side anastomosis of left renal artery to dacron graft.

circulation, and performance of the procedure in a manner to minimize the period of circulatory arrest (Fig. 33). Replacement of the excised segment of the aorta may be done with the use of an aortic homograft or a suitable substitute of plastic materials, such as nylon or dacron woven tubes. In recent years, our experience has led us to believe that the flexible, knitted, seamless dacron tube is the most satisfactory vascular replacement for this purpose.

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Drawing showing method of resection of aneurysm of abdominal aorta. a, after entering cavity through long mid-line incision, the small intestine and its mesentery are retracted to ie aneurysm is exposed by linear incision of overlying peritoneum with mobilization of surround- 'es. Umbilical tapes encircle aorta immediately above aneurysm and common iliac arteries im- below. Occluding clamps are then applied at level shown by encircling umbilical tapes and esected. Excised segment of aorta is then replaced with graft. b, anastomosis of graft to proximal aorta is shown using laterally placed anchoring sutures of No. 0000 arterial silk. c, one of the ien used to perform the posterior layer of the anastomosis using continuous through-and-through the other suture is used to complete the anterior layer of the anastomosis. e, after completing iortic anastomosis and the left common iliac anastomosis, blood flow through graft and into left emity is restored while remaining anastomosis to right common iliac artery is being performed.

ɔeripheral manifestations may de- erebral or neurologic disturbances, rly hemiplegia or paraplegia, are not on, while in some cases abdominal ıs may be predominant. In still other ıal disturbances and even renal fail- develop. Not infrequently, interfer- h peripheral arterial flow in the ex- ; occurs and may be erroneously :d to acute arterial embolism.

ional findings on examination in- e presence of an aortic diastolic mur- from one fourth to one half of the 'hich is particularly significant in pa- ı whom such a murmur did not exist previously. Hypertension is present in more than half the cases. Rarely ecchymosis in the lower part of the neck, upper portion of the chest, or lumbar or abdominal area may be observed.

Diagnosis. The most important factor in the diagnosis of dissecting aneurysm is awareness of its possible occurrence, particularly in the presence of the characteristic clinical manifestations. The acute onset, the severe chest pain, the subsequent radiation or "marching" of manifestations to other regions, and the history of hypertension are highly suggestive of the diagnosis. In its early stages the clinical picture is most often con-

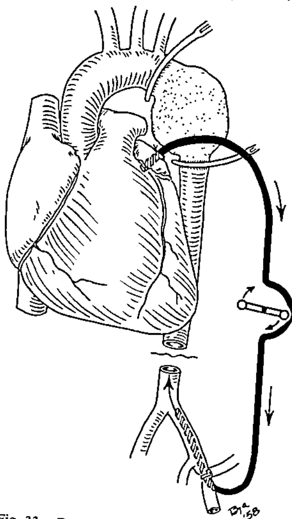


Fig. 33. Drawing illustrating method of resection of fusiform aneurysm of descending thoracic aorta with the use of controlled extracorporeal circulation to overcome ischemic effects of arrest of aortic circulation during performance of procedure. Oxygenated blood is removed from left auricle by means of plastic catheter inserted through appendage and then pumped into distal aorta through catheter inserted into left common femoral artery.

distention of the aorta, fixation of the ends of the aortic arch by the pulmonary artery and bronchi, and sudden increase in blood pressure from trauma or other causes.

The dissection commonly begins as a transverse tear in the intima and media a few centimeters above the aortic valves or in the descending thoracic aorta near the origin of the left subclavian artery or in the ligamentum arteriosum (Figs. 35, 38). Once this occurs, separation of the intramural layers of the aorta by the forceful stream of blood produces dissection, usually at the junction of the middle and outer thirds of the media.

This dissection may then progress circumferentially to involve all or a portion of the aorta and distally down to the bifurcation and even lower to invade the femoral arteries. As branches are encountered, they may be sheared off, or the dissecting process may extend along them for varying distances, thus diminishing or completely interrupting the blood supply to these areas. The extent and course of this process are variable. In the most acute and severe form dissection is rapid, and finally, terminal perforation occurs through the adventitia into the pericardium, mediastinum, pleural or peritoneal cavities, with death in a few hours or days. The subacute type may begin abruptly but may then progress gradually over a period of days or weeks to terminal adventitial rupture and death. In still other more chronic forms of the disease, the dissected passage may reenter the true lumen of the aorta to form a "double-barreled" aorta (Fig. 38). The false passage may then become covered with an endothelium or become obliterated by formation of thrombi and subsequent fibrous tissue organization.

Clinical Manifestations. Owing to the variation in extent and progression of the dissecting process, the clinical manifestations may be protean, with symptoms and signs occurring first in the chest and then extending more or less rapidly to other regions, such as the back, head, neck, shoulders, abdomen, groin, and lower extremities. This sequence or "marching" of manifestation from one region to another is a reflection of the progress of the dissection and the consequent injurious or ischemic effects upon the organs supplied by the major arterial branches of the aorta.

Perhaps the most striking manifestation of the disease is the sudden onset of severe, almost indescribable pain in the chest or epigastrium which may extend along the course of the ribs to the back and then up into the neck and shoulders or down into the abdomen. In some instances, the onset may be marked by loss of consciousness. Shock with significant lowering of blood pressure is frequently present. Depending upon the degree of interference with blood supply to the central nervous system, abdominal viscera, or extremities, a variety of neurologic abdomi-

Fig. 36. Roentgenograms of chest of patient with dissecting aneurysm of thoracic aorta showing, left, (posteroanterior projection) characteristic widening of supracardiac mediastinal shadow with relative radiolucence in its more peripheral part; and, right, (oblique view) widened and elongated shadow of descending thoracic aorta.

Fig. 37. Angiocardiogram of same patient as Figure 36 showing characteristic double aortic lumen produced by relative difference in concentration of dye in true and false aortic lumens of dissecting aneurysm.

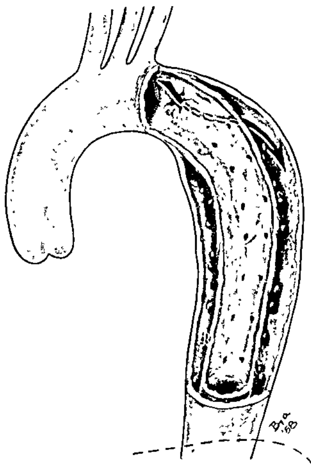


Fig. 35. Drawing illustrating gross pathologic features of dissecting aneurysm of aorta in which the dissecting process arises below the level of the origin of the left subclavian artery. Part of wall has been cut away to show separation of medial layer with false lumen surrounding true lumen and intimal tear through which lumens communicate.

fused with that of myocardial infarction, but in most cases of dissecting aneurysm, the electrocardiogram shows either a normal pattern or evidence only of left ventricular hypertrophy. The occurrence, however, of an electrocardiographic picture of acute coronary occlusion does not exclude the presence of dissecting aneurysm.

Perhaps the most significant diagnostic studies are those obtained by roentgenologic examination. Characteristically, roentgenograms of the chest show widening and radiolucence of the aortic arch and descending thoracic aorta. The most common finding is widening of the supracardiac shadow, involving the entire thoracic aorta or some segment of it (Fig. 36). This may be better evaluated by comparison with roentgenograms of the chest taken prior to the dissection. Another common radiologic finding is that of a double aortic shadow, consisting of a somewhat dense central core and an outer, more radiolucent portion representing the dissected passage. Evidence of pleural effusion, particularly on the left, is another important feature. Sectional roentgenography may also provide characteristic findings, demonstrating widening of the ascending aortic arch, and thus may permit differentiation of a nonvascular mediastinal lesion. Angiocardiography is probably the most valuable diagnostic procedure. In this type of examination the dye appears heavily concentrated in the true aortic lumen, whereas the false passage appears as a lateral or medial, somewhat superimposed, less dense channel (Fig. 37).

Prognosis. The prognosis in dissecting aneurysm of the aorta is extremely grave. In the classic study by Shennan, for example, death occurred within 24 hours after onset in 58 per cent and in one day to one week in 26 per cent of the patients. Somewhat similar figures have been reported by others. Death may occur rapidly from rupture into the pleural, pericardial, or peritoneal cavities or more slowly from progressive mediastinal or retroperitoneal hemorrhage, cardiac failure, or renal failure. Only in about 10 to 15 per cent of patients with the chronic or healed type of dissection is there a chance of significant survival, and even in this group further dissection may take place or death may result from cardiac failure.

Treatment. Until recently, treatment of this condition was unsatisfactory. In recent years, however, a method has been devised that appears to provide an effective surgical approach to the disease. The underlying principle of this approach is based upon nature's method of healing in which spontaneous re-entry of the dissected passage at some distal point in the aorta permits restoration of peripheral circulation, removes the increasing tension upon the outer wall, and thus prevents its rupture. The operative procedure is thus directed toward interruption of the progress of the dissection by creation of conditions compatible with function or correction of the process by actual removal and repair.

Accordingly, two methods of surgical

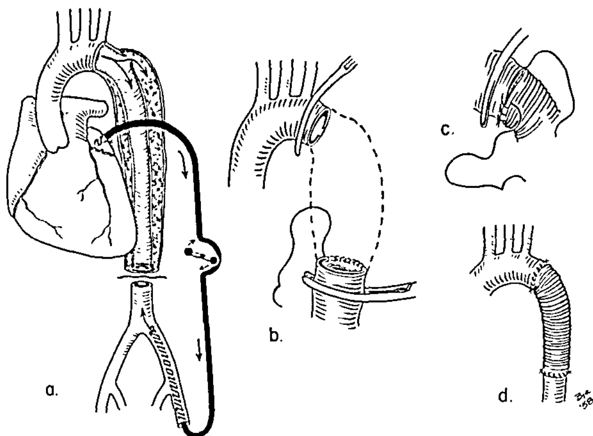


Fig. 39. Drawing showing method of surgical treatment of dissecting aneurysm of aorta using controlled extracorporeal circulation to combat ischemic effects of arrest of blood flow in aorta. a, blood is removed from left auricle through catheter inserted in auricular appendage and pumped into distal aorta through catheter inserted in left common femoral artery. By this means circulation is maintained in aorta distal to site of application of occluding clamps for resection of aneurysm. b, after excising segment of dissecting aneurysmal process above its origin, the false lumen in the distal end is obliterated by sewing outer and inner walls together with continuous suture. c, anastomosis of graft to upper aortic opening is done by continuous suture with No. 0000 arterial silk. d, completed anastomosis of graft to lower opening in aorta permits restoration of aortic continuity.

riche's syndrome, is a distinct clinical and pathological entity characterized by partial or complete obstruction of the aorta in the region of its bifurcation and producing manifestations of arterial insufficiency of the lower extremities. Although sporadic reports describing the condition had appeared much earlier, Leriche deserves credit for directing attention to the condition as a definite entity, first in 1923 and later for a more thorough description of the syndrome and its differentiation from other vascular disturbances. Since then, and probably as a consequence of the further interest that was aroused by these reports and by the wider use of aortography, it is now recognized as one of the most common causes of arterial insufficiency of the lower extremities. The predominant etiologic factor responsible for this condition is arteriosclerosis or atherosclerosis, and only rarely do other factors, such as trauma, thromboangiitis obliterans, and atypical forms of coarctation, play a role in its causation.

Pathology. The arteriosclerotic lesion begins with intimal proliferation and deposition of lipid material in the subintimal layer of the arterial wall. Continuing deposition of this substance and local changes in the deposit itself result in the formation of an atheroma. This lesion may be extensive, but it is more frequently localized, often being only a few centimeters in length. As the atheroma enlarges, it tends to project into the arterial lumen, gradually producing obstruction to





Fig. 38. Photographs of resected segment of dissecting aneurysm of thoracic aorta removed at operation in same patient as Figures 36 and 37 showing, left, gross appearance of intact specimen with arrows above and below representing true lumen; and, above, sagittal view with arrow pointing to intimal tear through which true lumen communicated with false lumen. Lower end of this photograph shows cross sectional view of specimen demonstrating characteristic "double-barreled" aorta with smaller true lumen and larger false lumen produced by dissecting aneurysm.

treatment may be employed, depending upon the site and extent of the dissecting process. The first is indicated in cases in which the dissection begins in the ascending aorta and consists of creation of a re-entry passage from the false to the true aortic lumen. This is done by cross-clamping the descending thoracic aorta, dividing it completely between clamps, obliterating the false passage below by approximating the outer and inner layers, excising a small segment from the inner wall above to permit re-entry into the true lumen, and then completing the procedure by end-to-end anastomosis. Blood flow is then directed from the double aortic lumen above into the single normal lumen below.

The second method is indicated in cases in which the dissection begins near the origin of the left subclavian artery and may be considered a more curative procedure since it removes the origin of the dissecting process and obliterates the false passage (Fig. 39). It consists of excision of the segment involved in the origin of the dissection and replacement with an aortic homograft after the distal false passage has been obliterated by suturing together the edges of the inner and outer walls. An important consideration in the postoperative management is control of hypertension. Results of this form of therapy have been quite gratifying. The operative mortality has been about 25 per cent, and follow-up observations during a period of more than three years have indicated maintenance of good functional activity.

THROMBO-OBLITERATIVE DISEASE OF THE ABDOMINAL AORTA

Thrombo-obliterative disease or arteriosclerotic occlusive disease of the abdominal aorta, also termed insidious thrombosis of the aorta, chronic aortoiliac thrombosis, or Le-

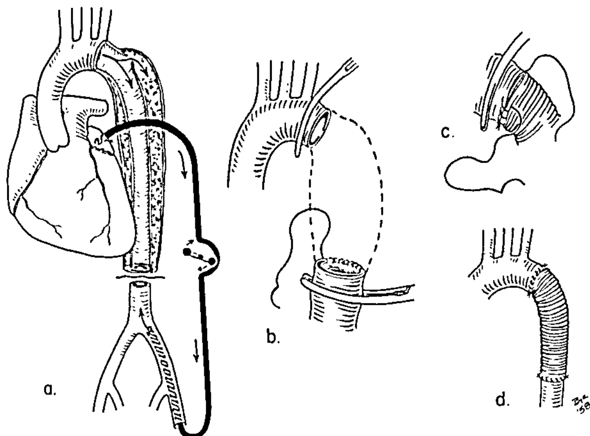


Fig. 39. Drawing showing method of surgical treatment of dissecting aneurysm of aorta using controlled extracorporeal circulation to combat ischemic effects of arrest of blood flow in aorta. a, blood is removed from left auricle through catheter inserted in auricular appendage and pumped into distal aorta through catheter inserted in left common femoral artery. By this means circulation is maintained in aorta distal to site of application of occluding clamps for resection of aneurysm. b, after excising segment of dissecting aneurysmal process above its origin, the false lumen in the distal end is obliterated by sewing outer and inner walls together with continuous suture. c, anastomosis of graft to upper aortic opening is done by continuous suture with No. 0000 arterial silk. d, completed anastomosis of graft to lower opening in aorta permits restoration of aortic continuity.

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Pathology. The arteriosclerotic lesion begins with intimal proliferation and deposition of lipid material in the subintimal layer of the arterial wall. Continuing deposition of this substance and local changes in the deposit itself result in the formation of an atheroma. This lesion may be extensive, but it is more frequently localized, often being only a few centimeters in length. As the atheroma enlarges, it tends to project into the arterial lumen, gradually producing obstruction to



Fig. 40. Sagittal section of resected segment of abdominal aorta and bifurcation in a case with complete occlusive disease, showing extensive atheromatous mural changes, most pronounced in region of bifurcation, with superimposed thrombosis in various stages of organization.

blood flow. At first only partial interference to circulation occurs, but as the lumen becomes reduced to a critical level, thrombosis develops so that the arterial lumen becomes completely occluded. With the development of a superimposed thrombus, the occluding lesion extends both proximally and distally until a collateral arterial channel is reached, through which blood flows at a rate vigorous enough to prevent thrombosis. The occluding lesion under these circumstances consists of the atheromatous mass and thrombus in various stages of organization. The intraluminal thrombus undergoes reorganization by fibrous tissue, and the inflammatory reaction of healing incited by the thrombus and the foreign-body reaction stimulated by the atheroma produce local arterial invasion by fibrous tissue that results in the incorporation of the involved arterial segment within dense fibrous or scar tissue. The extent of this reaction depends, of course, on the duration of the occlusion. Acute occlusions may show little or no such reaction while those of long duration may be associated with advanced changes. The terminal aorta in patients with longstanding disease has occasionally been found to be largely replaced by, or incorporated in, dense fibrous scar tissue.

The arteriosclerotic lesion producing obstruction of the aortic and iliac arteries is located in the common iliac artery, either at its bifurcation into external and internal iliac arteries or at its origin from the aorta, and may assume several recognizable forms depending upon the degree and extent of involvement. Accordingly, it may be classified into those producing 1. incomplete or 2. complete occlusion. In the former type the lesion is limited to the atheroma and may involve one or both iliac arteries. In some instances, one of the common iliac arteries becomes completely occluded, the lumen being filled with organizing thrombus superimposed on the atheromatous lesion. When both common iliac arteries become similarly involved, the terminal aorta becomes completely occluded and the thrombotic process

gradually propagates upward to the renal arteries, and ultimately occlusion of these vessels may occur with terminal renal failure (Fig. 40).

Histologic studies of the diseased segments further support the concept that the occlusive pathologic changes arising about the aortic bifurcation and common iliac arteries can extend by propagation of the thrombotic process to an adjacent portion of the aorta (Fig. 41). Although it is conceivable that the partially occlusive lesions of the iliac arteries represent stages in the development of disease toward complete aortic occlusion, certain significant differences have been observed in these two forms of the condition. Among these the most impressive feature has been the fact that a high proportion of the cases with complete aortic occlusion seem to have a well-localized process, with the obliterative lesion confined to the terminal aorta and bifurcation and with a relatively normal patent peripheral arterial bed (Figs. 42, 43). On the other hand, in those with incomplete occlusion, the disease tends to be much less localized and to be more commonly associated with atherosclerotic occlusive lesions of the peripheral arterial tree (Figs. 44, 45).

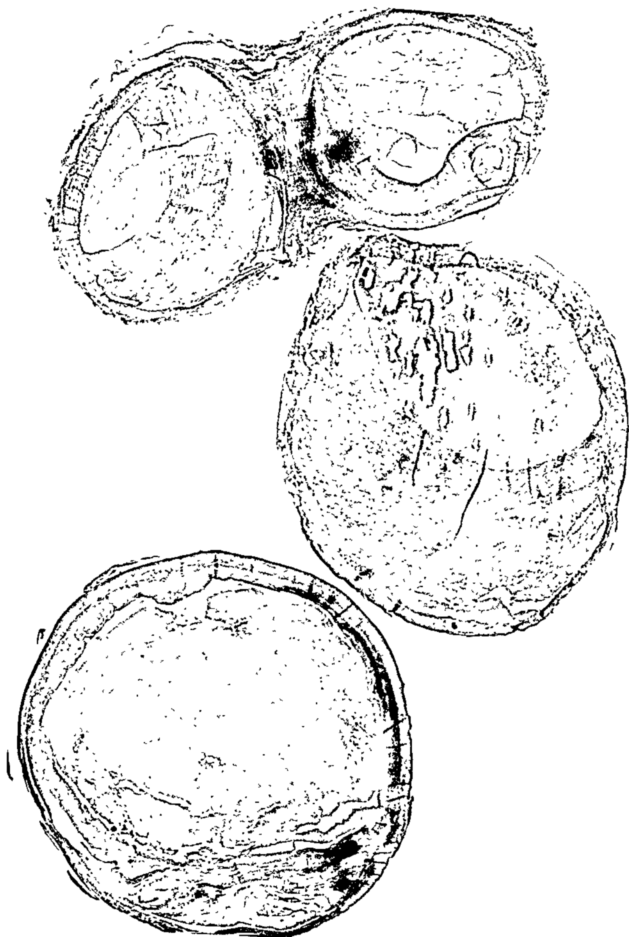
This process of occlusion fortunately is gradual, and because of its frequently insidious nature, collateral channels are able to enlarge as the main arterial routes become progressively obstructed. As a result of this natural alteration, gangrene usually does not occur immediately after occlusion; however, in view of the reduction in the volume of peripheral blood flow, chronic arterial insufficiency ensues.

Clinical Considerations. The disease occurs predominantly in the male sex in the fifth to seventh decades of life. In our series the ratio of males to females was approximately 10:1. Among the patients with diabetes, however, this difference in sex ratio was much less pronounced. In this connection, too, diabetes was most commonly encountered in the younger age group. Approximately 90 per cent of the cases occur in the fifth, sixth, and seventh decades, with the highest incidence, approximately 40 per cent, in the sixth decade. The youngest patient in our series of cases was 26 years of age and the oldest 81 years. Of particular significance is the fact that patients with complete occlusion of the aorta were, on the average, about a decade younger than those with incomplete occlusion.

The symptoms and physical findings of chronic occlusion of the aorta and iliac arteries vary with the extent and duration of ischemia as well as with the location of the lesion. The clinical manifestations may be mild, moderate, or severe. In the earlier stages of the disease, the patients have only mild intermittent claudication and complain of a feeling of fatigue, weakness, or tightness in the lower legs or thighs on walking a short distance. Characteristically, these sensations disappear almost immediately upon resting, only to return again on further walking. On physical examination, pulses in the lower extremities are diminished or absent and the other signs of ischemia are often absent. Occasionally, no abnormalities are found; however, the intermittent nature of the complaint, occurring only during episodes requiring increased circulation, is highly suggestive of early arterial insufficiency, and additional specialized studies to be described later are advisable. In these cases, the lesion is still well localized and usually only partially occludes the arterial lumen.

As the disease progresses, evidences of moderately severe peripheral ischemia become apparent. This is manifested by rather severe pain when the patient walks short distances, resulting in considerable limitation of his routine activities. The pain may occur in any part of the lower extremities but often is first noted in the thighs, buttocks, or in the back. The most significant finding on physical examination is absence of pulses throughout the extremity. Other findings are atrophy of the involved extremities, loss of hair, and decreased temperature of the feet. If obstruction is unilateral, the clinical manifestations will, of course, be limited to the involved side.

In the more advanced stages of the disease, manifestations of ischemic changes that are pregangrenous or associated with early gangrenous lesions develop. Such patients have severe or terminal arterial insufficiency and unless properly treated are destined to have



amputation. These patients usually have had mild to moderate manifestations of the disease for years, with gradual progression until pain is present at rest (rest pain), particularly at night when the extremities are elevated (night pain). On physical examination the examiner notes absent pulses beyond the point of obstruction in the involved extremities, cold extremities, blanching on elevation, dependent rubor, slow venous filling, and cutaneous lesions ranging from ulceration to gangrene.

Diagnosis. The diagnosis of this disease can usually be made on the basis of the characteristic clinical manifestations and physical findings. Of particular significance in this connection is its differentiation from Buerger's disease or thromboangiitis obliterans, since the more effective forms of surgical treatment, such as thromboendarterectomy and arterial graft procedures, are generally not applicable to the latter condition. Buerger's disease may be readily differentiated clinically from this form of arteriosclerotic occlusive disease of the aorta on the basis of several characteristic features. For one thing, Buerger's disease characteristically begins in the third or fourth decade of life and only rarely is its onset in the fifth decade. Arteriosclerotic occlusive disease, on the other hand, becomes manifest later in life, usually in the fifth to the seventh decades. A history of migratory phlebitis may often be elicited in Buerger's disease and is not a characteristic feature of arteriosclerotic occlusive disease. Moreover, Buerger's disease usually involves the medium sized vessels and tends to appear first in the arterial tree below the knee and only in its later stages does it involve the femoral artery in the region of the groin. Accordingly, femoral arterial pulsations are usually present in Buerger's disease, whereas in arteriosclerotic occlusive disease of the terminal abdominal aorta, femoral arterial pulsations are absent or greatly diminished. In doubtful cases, however, and in all cases in which occlusion in the iliofemoral region is suspected, arteriographic studies are essential not only to confirm the diagnosis but also to demonstrate the presence or absence of a patent segment of artery distal to the occlusion.

Although the diagnosis of thrombo-obliterative disease of the abdominal aorta can usually be made on the basis of the characteristic clinical findings, certain additional methods of study may be necessary in order to confirm the diagnosis and to provide information essential to proper therapy. Among these, lumbar aortography is the most important because it not only establishes the diagnosis but it also provides precise information concerning the location of the occlusive lesion and its extent both proximally and distally (Figs. 42, 43, 44, 45). In this procedure, radiopaque material is injected into the abdominal aorta above the lesion and an abdominal roentgenogram is taken immediately on completion of the injection. The distal aorta and iliac arteries are thus visualized, so that the presence, nature, and extent of the lesion can be determined. Technically, this procedure is performed with use of a local or general anesthetic with the patient lying prone over the cassette containing the x-ray film. A seven-inch No. 17 gauge needle is inserted through the back on the left into the abdominal aorta opposite the twelfth dorsal vertebra. An organic iodide compound, preferably 70 per cent Urokon, is injected in doses of 30 ml. or less and the x-ray film is exposed as the injection is being completed. This technic of aortography has proved safe and satisfactory in our hands in more than 350 consecutive cases.

Treatment. Treatment of arterial insufficiency is directed toward restoration of a pulsatile blood flow throughout the lower extremities. The restored circulation permits return of normal function and provides normal reparative powers for the extremity. The localized nature of the occlusion, being as-

Fig 41 Low power photomicrographs of cross sections of aorta at various levels in resected specimen in case of thrombo-obliterative disease of aorta. Top, section taken at level of aortic bifurcation near origin of common iliac arteries, showing characteristic extensive atheromatous mural changes and superimposed thrombotic process producing complete occlusion of lumens. Middle, section taken at higher level near origin of inferior mesenteric artery, showing somewhat less extensive atheromatous mural involvement with organized thrombus occluding remaining lumen of aorta. Bottom, section taken at a still higher level on the aorta a few centimeters below origin of renal arteries shows progressive diminution in extent of atherosclerotic mural changes with more freshly organized thrombus filling lumen of aorta.



Fig. 42. Lumbar aortogram in a patient with thrombo-obliterative disease of abdominal aorta showing complete obstruction of aortic lumen. Occlusion arises just above bifurcation and extends distally to involve iliac arteries, but the femoral arteries are patent, thus demonstrating characteristic segmental nature of occlusive lesion.



Fig. 43. Lumbar aortogram in patient with thrombo-obliterative disease of abdominal aorta. The occlusive lesion has progressed proximally to origin of renal arteries and is beginning to encroach upon opening of right renal artery. Distally the occlusive process involves the iliac arteries, but the femoral arteries below this level are patent. (Note silver clips on each side of lumbar vertebrae representing lumbar sympathectomy performed previously for treatment of arterial insufficiency of lower extremities.)



Fig. 44. Lumbar aortogram in patient with thrombo-obliterative disease of abdominal aorta of the incomplete occlusive type associated with segmental occlusion of right femoral artery.

sociated in most cases with reasonably normal channels both above and below the obstruction, permits application of recently developed vascular technics for this purpose. These include thromboendarterectomy, excision of the obstructive arterial segment with graft replacement, bypassing the occlusion by means of end-to-side anastomoses of the graft above and below the lesion, or a combination of these procedures (Fig. 46). The indications for these various methods of treatment are dependent upon the location, extent, and nature of the occlusive process.

Short, discrete, occlusive lesions in vessels with normal outer layers may be simply removed by thromboendarterectomy. A well-defined cleavage plane exists between the involved intima and the uninvolved medial layer of the artery. Thromboendarterectomy is performed by temporarily occluding the artery to prevent bleeding, opening the involved artery, dissecting out the obstruction through the plane previously mentioned, and suture repairing the incision in the artery (Figs. 47, 48). Since this procedure is simple to perform and obviates the need for an arterial substitute, it would appear to be the ideal operation; however, it can be satisfactorily applied in only about one third of the cases.

In some patients, the arteriosclerotic lesion may involve the outer layers of the arterial wall to such extent that endarterectomy is not feasible. In cases of this type in which the mural atherosclerotic process about the bifurcation is extensive and destructive but fairly well localized, resection with graft replacement is the procedure of choice. In still other patients, the occlusion may involve a long segment of the aorta, common and external iliac arteries. Under these circumstances, both endarterectomy and excision with graft replacement may be undesirable because of the extent of the operative procedures on the one hand and the risk of collateral vascular injury on the other. Rather, it is preferable to bypass the region of disease. This is accomplished by suturing the ends of a suitable arterial substitute both above and below the occlusion without significantly disturbing the collateral channels (Fig. 49). Although both homografts and various types of plastic tubes have been successfully employed for vascular replacements, the most satisfactory material in our experience for this purpose has proved to be a specially designed flexible dacron tube available in different sizes and with branches

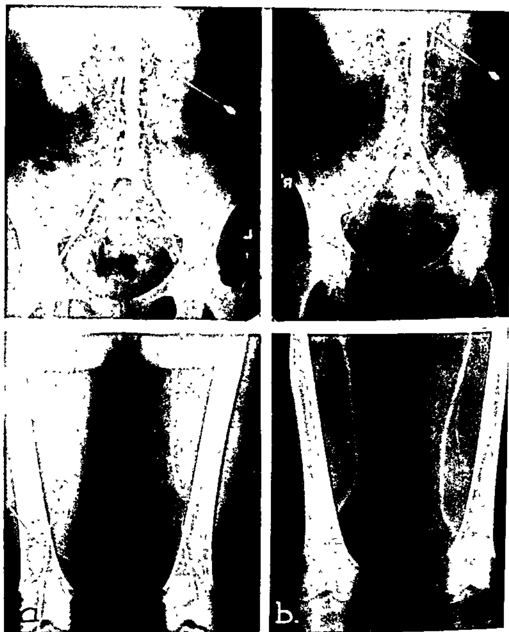


Fig. 45. a, lumbar aortogram made preoperatively in patient with incomplete occlusion of terminal abdominal aorta and iliac arteries associated with segmental occlusion of both femoral arteries. b, lumbar aortogram made following surgical treatment, consisting of thromboendarterectomy of abdominal aorta and iliac arteries and bypass grafts from femoral to popliteal arteries bilaterally, showing restoration of normal circulation.

for replacement of any operable arterial segment (Fig. 49).

All patients with arteriosclerotic occlusive lesions of the distal aorta and iliac arteries are candidates for one or a combination of these forms of therapy, and normal circulation can be restored in almost all instances with relief of symptoms and preservation of extremities. This approach, however, is rarely applicable in occlusive lesions of the aorta and iliac arteries as a result of thromboangiitis obliterans. This lesion is diffuse, and by the time the larger channels have become involved, the smaller distal vessels have already become occluded; and in the absence of distal patent channels, direct operative measures are impossible. Under these circumstances, treatment is directed toward increasing collateral blood flow, local protective care of the lower extremities, and

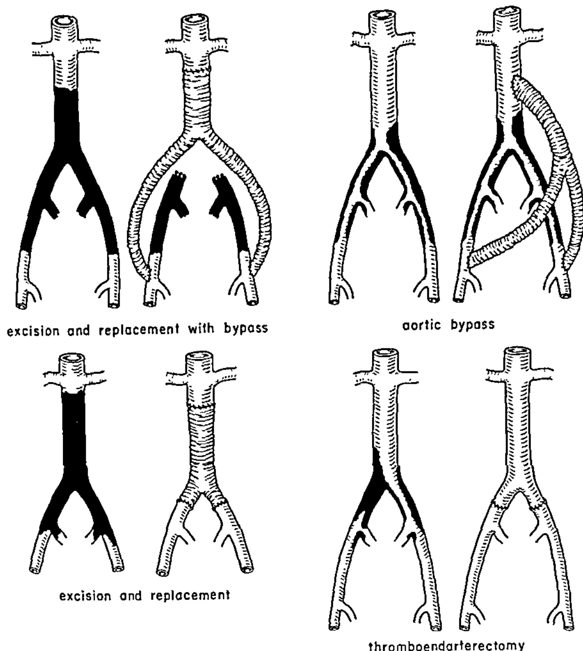


Fig. 46. Diagrammatic drawing showing various methods of surgical treatment of thrombo-obliterative disease of abdominal aorta.

withdrawal of harmful influences. By eliminating vasoconstrictor tonus and increasing cutaneous blood flow, lumbar sympathectomy is the most helpful and constant method of promoting collateral circulation and should be considered in every case. Daily foot baths should be taken to promote cleanliness and prevent infection. Habitual use of tobacco and other vasoconstrictor agents should be prohibited in order to obtain the maximum blood flow.

The results obtained by these methods of direct operative treatment of thrombo-obliterative disease of the abdominal aorta and iliac arteries have been most gratifying. In our series of over 400 cases in which these methods of therapy have been employed, excellent results with complete relief of symp-

Fig. 47. Drawing illustrating a, type of well-localized lesion in which thromboendarterectomy may be performed satisfactorily; b, technic of performance of procedure by applying occluding clamps above and below the lesion to arrest circulation through the segment of vessel following which right iliac artery is transected; and c, d, separation of thrombotic and intimal occlusive processes from outer adventitial and medial layer of artery by well-developed cleavage plane; e, following complete removal of the occlusive process, arterial continuity is restored by end-to-end anastomosis of vessels.

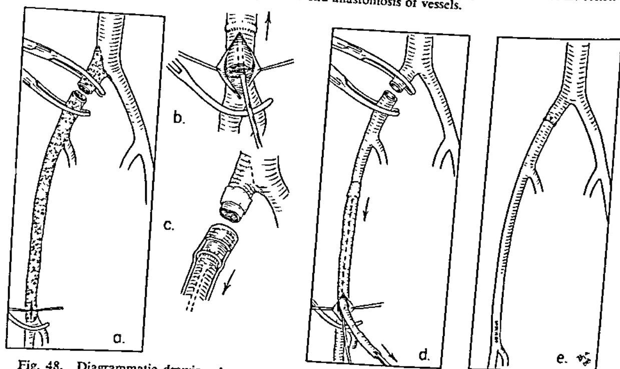


Fig. 48. Diagrammatic drawing showing method of performing thromboendarterectomy in external iliac artery using ring strippers developed by authors for this purpose.

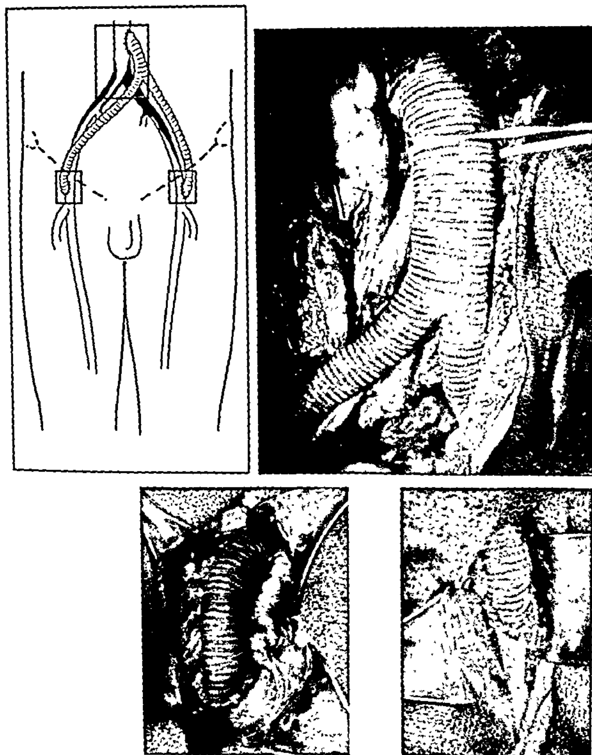


Fig. 49. Photographs made at operation showing completed procedure of bypass dacron graft from abdominal aorta above to both common femoral arteries below as diagrammatically illustrated in upper left.

toms and restoration of normal pulsatile circulation in the lower extremities was obtained in approximately 90 per cent of the cases. The risk of operation is relatively low, the operative mortality in our series being only about 2 per cent.

In the selection of patients for this form of surgical treatment, our experience would suggest that it is applicable in the majority of patients with this type of arteriosclerotic occlusive disease of the abdominal aorta and iliac arteries. There are few contraindications to operation, the most important being the presence of severe or disabling cerebral, cardiac, pulmonary, or renal systemic disease. Compensated heart disease, hypertension, and diabetes are not contraindications to operation. Age in itself is also not a contraindication to operation.

THROMBO-OBLITERATIVE DISEASE OF THE BRANCHES OF THE AORTIC ARCH

Thrombo-obliterative disease of the branches of the aortic arch is a clinical entity resulting from occlusion of one or more of the major branches arising from the aortic arch. It is also known as the aortic arch syndrome, pulseless disease, reverse coarctation, Takayasu's disease, and Martorell's syndrome.

Although the condition was well described by Broadbent in 1875, except for Takayasu's report in 1908 and subsequent reports of other Japanese ophthalmologists, little interest has been shown in the disease until recently. Shimizu and Sano, in 1951, received wide recognition for their report with its eye-catching title, "Pulseless Disease," and undoubtedly caused greater awareness of the condition. Since then, an increasing number of reports has appeared in both the American and the European literature. Contrary, however, to the earlier indications that the disease was predominantly of Japanese origin, these recent reports suggest that it has widespread geographical distribution and probably occurs more frequently than previously realized.

The etiology is not entirely clear although various contributing etiologic factors have been proposed, including syphilitic aortitis, aneurysm of the aortic arch, nonspecific arteritis, atheromatosis, and trauma. More recent pathologic study of specimens removed surgically indicates that arteriosclerosis is perhaps the most frequent cause of this condition. The most important pathologic feature of the lesion is its localized nature, involving primarily the innominate, carotid, and subclavian arteries (Figs. 50, 51). Although all branches of the aortic arch may be involved, the lesion may be localized to only one branch. The disease rarely extends beyond the course of these vessels in the neck and proximally is limited to their origin from the aortic arch. Thus the obliterative lesion is segmental in character with relatively normal arterial lumens both above and below the occlusion. In this respect, the disease appears to be similar to the Leriche syndrome (thrombo-obliterative disease of the abdominal aorta).

Clinical Considerations. The clinical manifestations are those of arterial insufficiency and depend upon the aortic branch involved and the extent of the occlusive process. In general these may be considered according to the part affected by the arterial insufficiency: brain, eyes, face, and upper extremities. The neurologic symptoms vary from mild headache, vertigo, and syncope to complete paralysis. Symptoms referable to the eye consist of varying degrees of temporary blindness. In the face, atrophy of skin and muscle is common and actual ulceration may be present. In the upper extremities, symptoms are usually mild, consisting of weakness, intermittent claudication, and easy fatigability.

The most striking findings on physical examination are absence of peripheral pulses beyond the point of occlusion. Occlusion of the innominate artery is associated with absence of pulses in the right side of the neck and in the right arm. Separate origins of the left carotid and left subclavian arteries from the aortic arch make involvement of both arteries necessary to produce arterial insufficiency and absence of pulsations in the left side of the neck and in the left arm.

The precise location and extent of the lesion is determined by angio-aortography. In this procedure 50 ml. of a 70 per cent solu-

Fig. 50. Drawing showing a, complete segmental occlusion involving innominate artery arising at opening from aortic arch and extending to bifurcation of common carotid artery; and b, method of treatment my using bypass dacron graft from ascending aorta to right subclavian and right common carotid artery.

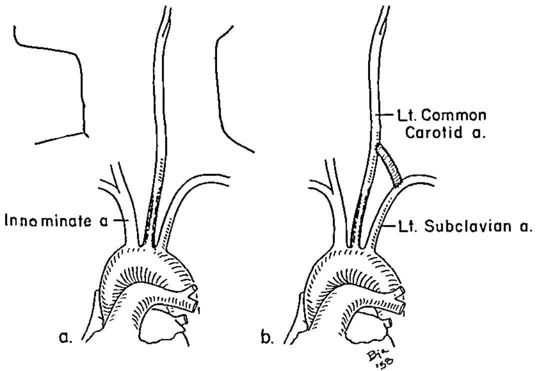


Fig. 51. Drawing illustrating a, segmental occlusion involving left common carotid artery which is incomplete but well-localized; and b, method of treatment by use of bypass graft from uninvolved left subclavian artery to left common carotid artery distal to site of occlusion.

tion of Urokon is injected into an antecubital vein and a roentgenogram is made of the chest and neck after an interval equal to the previously determined arm-to-tongue circulation time. At the time of exposure, the contrast material is located in the aortic arch and its major branches. The occlusive lesion in these vessels is outlined by its displacement of contrast material.

Treatment. Effective therapy is surgical and is directed toward restoration of normal pulsatile blood flow distal to the occlusion. The localized nature of the lesion permits application of the direct operative measures previously described for thrombo-obliterative disease of the aorta. In the milder forms of the disease, when the lesion is short and well localized, the occlusive segment may be removed by thromboendarterectomy. The use of an end-to-side bypass graft is technically easier and safer for the more diffuse lesions. Occlusive lesions of the innominate artery require a bifurcation graft (Fig. 50). The main trunk of the bifurcation graft is sutured to the ascending aorta, and the two remaining limbs of the graft are sutured to the right subclavian and right carotid arteries respectively. An occlusive lesion of the left common carotid artery may be bypassed by suturing one end of a graft to the aortic arch and the other to the cervical segment of the carotid artery. If the left subclavian artery is not involved, an occlusive lesion of the left carotid artery may be more simply bypassed by suturing one end of a graft to the supraclavicular segment of the left subclavian artery and the other end to the carotid distal to the occlusion (Fig. 51). Occlusion of the left subclavian artery, when short, is discrete and may be treated by endarterectomy. More extensive occlusions are bypassed from the aortic arch proximally to the normal artery distal to the occlusion.

The results of this form of therapy have been highly gratifying, with restoration of normal pulsatile circulation to the parts beyond the obstructing lesion in over 90 per cent of the cases. Restoration of normal circulation has provided relief of symptoms and resumption of normal activity. In our series of about 25 cases there has been no mortality.

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39

THE ENDOCRINE GLANDS

In spite of constantly accumulating knowledge concerning the functions of the endocrine glands, endocrinology remains complex. The treatment of many of the diseases of these glands is primarily surgical. It is probable that, as more knowledge accumulates in this field, still more surgical procedures will be adaptable for treatment of disease of these organs. However, the complexity of certain of the endocrine glands interferes considerably in diagnosis and in the application of various therapeutic procedures. Many of the glands contain more than one type of secreting structure, such as the medulla and cortex of the adrenal and the anterior and the posterior lobes of the pituitary gland. Many of them are directly affected in their activity by impulses carried by the autonomic nervous system. Finally, the endocrines have an intimate relationship to each other, reacting in a balanced antagonistic or synergistic manner (Fig. 1). The production of hyperactivity of the thyroid gland by an extract of the anterior pituitary gland is an example of the relationship of one gland to the function of another. The pituitary gland (anterior lobe particularly) is known to exert important controlling influences not only over the thyroid but also over the adrenal cortex and the gonads. The stimulation of the adrenal cortex by ACTH (adrenocorticotrophic hormone), with production of cortisone and other steroids important in physiologic processes, illustrates the vital significance of the functions of the endocrine glands.

THYROID

Physiology. The thyroid is the most important organ in the body in the maintenance of metabolic rate at a level compatible with good health and efficiency, but it is not essential to life. The active principle of the thyroid is a tissue catalyst; it was isolated and named thyroxin by Kendall (1914) and synthesized a number of years later by Harington (1927). It has been estimated (Kendall) that there are about 14 mg. of thyroxin in the human body.

Our knowledge of the formation of thyroxin is not clear. However, it appears that iodine is converted to sodium iodide, which unites to tyrosine (by an oxidase reaction) to form diiodotyrosine. Another oxidation reaction combines two molecules of diiodotyrosine to form thyroxin, which is released under the control of the thyrotropic hormone of the anterior pituitary gland (1). Free iodinated amino acids, such as triiodothyronin, may exert a role in thyroid function, as indicated by their presence in the thyroid gland. Antithyroid drugs, such as propylthiouracil, reduce thyroid activity, presumably by blocking an essential oxidation step in the formation of thyroxin, thus interfering with the combination of iodine with tyrosine (2). In normal persons, excessive stimluation of metabolism by administration of thyroxin produces tachycardia, weakness, loss of weight, increased appetite, and other manifestations (except exophthalmos) noted in toxic goiter (hyperthyroidism). Diminution or depriva-

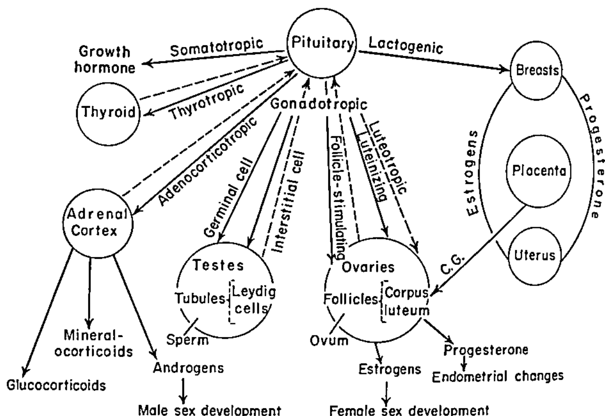


Fig. 1. Diagram of endocrine relationships. The solid lines with arrows indicate the glands stimulated and the hormones produced through the tropic, governing and regulatory activity of the anterior pituitary gland. The dotted lines with reverse arrows suggest the effects of the hormones of the "target glands" in reducing secretion of pituitary tropic hormones. During pregnancy the placenta produces large amounts of chorionic gonadotropin (C.G.) of estrogen, and of progesterone.

tion of the active principle of the thyroid gland in children produces a syndrome known as cretinism, in which stunted growth, dulled mentality, coarse features, and so forth, are prominent manifestations. An absence of thyroid secretion in adults produces myxedema, important manifestations of which are physical and mental lethargy, thick skin, and loss of hair, as discussed in detail later.

Classification of Diseases of the Thyroid Gland. Often there is confusion in the discussion of various diseases of the thyroid, primarily because many authorities use different terms to designate the same disease. It is important to standardize the classification in order to eliminate confusion which may arise by use of multiple terms. The classification (excluding tumors, thyroiditis, and hypothyroidism) recommended by a committee (3) appointed by the American Society for the Study of Goiter years ago appears still to be the most practical: diffuse nontoxic goiter, nodular nontoxic goiter, diffuse toxic goiter, and nodular toxic goiter.

DIFFUSE NONTOXIC GOITER

Although this type of goiter (frequently called simple colloid goiter) is the most prevalent of the various kinds encountered, it is the least serious from the standpoint of the effects on the patient. It is, to a certain extent, geographical but is encountered most commonly in young women at puberty, during pregnancy, or during some other functional strain.

Etiology. Years ago it was thought that a deficiency of iodine in food and water was the primary cause of nontoxic diffuse goiter. However, since the widespread use of iodized salt and wide distribution of food products from the various parts of the country have not eliminated the disease (even though a sharp decline in incidence is noted) it is obvious that some other factor is important

in causation. It is most likely that the numerous goitrogenic compounds (thiourea, thiouracil, thiocyanate, *sulfanilamides*) and foods (cabbage, rutabagas, soy beans, Brussels sprouts, cauliflower, 4) containing such products are of more importance. Years ago it was shown (McCarrison and associates, Cole and Womack, and others) that certain fats, contaminated food, and various types of chronic infections might produce goiter in animals. Heredity is at times a factor since mother and daughter often have the disease. This "hereditary" factor might not be truly hereditary, but rather congenital; it could be related to the ingestion of goitrogenic compounds by the mother during gestation, since it is know that ingestion of propylthiouracil by the mother during pregnancy may result in production of goiter in the newborn infant (*5*). *The circumstances mentioned above may* result in a failure of the enzymatic system of the thyroid to produce enough thyroid hormone; this failure probably results in compensatory action of the pituitary with production of abnormal thyroid response, i.e., goiter.

Pathology. The chief gross pathologic features of diffuse nontoxic goiter are a slight but generalized and symmetrical enlargement and hypertrophy of the gland, associated with the presence of an excess amount of colloid secretion as noted on cut section. Microscopically, the acini are larger than normal and the cells flattened. However, numerous areas of hyperplasia, consisting of heightening of the cells with layering and plication, are usually noted here and there throughout the gland.

Clinical Manifestations. The clinical manifestations of diffuse nontoxic goiter are really very few. The most important is enlargement of the neck, produced by the hypertrophied thyroid gland. This enlargement is never very marked; rarely does it constitute a cosmetic blemish, and in many instances is noticeable only on careful examination. The basal metabolism is normal or often, somewhat lower than normal. There is no tachycardia, tremor of the fingers, or exophthalmos. Rarely does this type of goiter become so large as to produce pressure symptoms related to breathing and deglutition. However, if present in a pregnant woman, this type of goiter, if untreated by iodine, or the like, may lead to the production of cretinism *in the offspring.*

Treatment. Treatment cannot be considered extremely important, because symptoms are rarely produced by this disease and because a mild hypertrophy appears as a normal physiologic phenomenon during puberty and pregnancy. However, there appear to be definite reasons for prophylactic therapy in goitrous regions by the routine administration of iodine. This favorable effect of iodine on the disease was first definitely demonstrated by Marine and Kimball (1921) when they reported the eradication and prevention of goiter in the school children of Akron, Ohio, through the administration of iodine in the drinking water. Only a few milligrams of iodine (either as a free element or as iodides) *per day is necessary. Beneficial effect is ob*tained by giving this small dose for a few days three or four times a year. Actually, there is enough iodine in iodized salt to supply this need.

Another indication for treatment lies in the fact that mild myxedema occasionally develops when a diffuse goiter has been present for a long time. When hypothyroidism is present, desiccated thyroid, 1 to 3 grains daily, should be given in addition to iodine. It is especially important that the goiter not be allowed to exist in women throughout the childbearing period since there is a definite tendency to transmit simple goiter congenitally, frequently with an associated cretinism in the offspring. Rarely does iodine fail to effect at least a significant decrease in the size of diffuse nontoxic goiters. With few exceptions, iodine will prevent the myxedema which is occasionally seen in this type of goiter, but of more importance is the fact that the drug, when given to a goitrous pregnant woman, will rarely fail to prevent the development of goiter in the child. Surgical excision in diffuse nontoxic goiter of recent duration is distinctly contraindicated since the enlargement is to a great extent physiologic, i.e., caused by the demand for increased thyroid secretion. In "goiter belts," diffuse nontoxic goiter frequently persists beyond the period of physiologic strain (puberty, pregnancy, and so forth). Not uncommonly it becomes nodular and takes on the character-

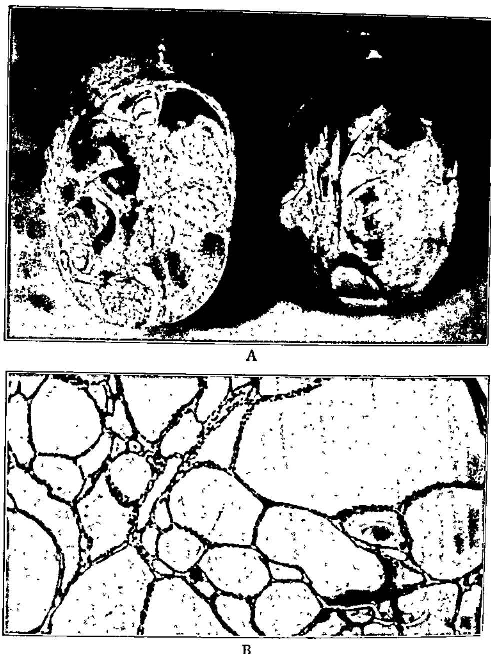


Fig. 2. Nodular goiter removed from a patient without evidence of hyperthyroidism. A, cut and external surface of a large nodule which represented an entire lobe on one side. Note the lack of homogeneity of the cut surface; this is produced by the profuse deposition of scar tissue and the large acini or cysts containing colloid. In its gross appearance, such a goiter can scarcely be differentiated from a toxic nodular goiter. B, microscopic section reveals flat acinous cells, scanty interstitial tissue, and large acini containing colloid. Such a gland is frequently spoken of as a colloid goiter.

istics of nodular nontoxic goiter as described below.

NODULAR NONTOXIC GOITER

The occasional transformation of diffuse nontoxic goiter to nodular nontoxic goiter as just described suggests that the latter is simply an advanced stage of the former, but proof is lacking.

The pathogenesis of nodular nontoxic goiter can best be understood by first outlining its *pathologic features*. Grossly, there is an asymmetrical enlargement of the gland with nodules distributed diffusely throughout. On cut section, the nodules are found to consist of tissue containing a large amount of glairy, gelatinous material which is called colloid (Fig. 2); hence, the frequent use of

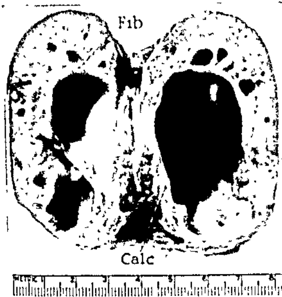


Fig. 3. Cystic adenoma. Note also fibrous tissue and calcification. Patient had no symptoms of hyperthyroidism.

the term colloid goiter. Occasionally, these nodules contain a thin brownish fluid (cystic goiter, Fig. 3). Less frequently, areas of hemorrhage are encountered. If the goiter has been present for several years, areas of calcification may be found in the fibrous tissue between the nodules. Microscopically, the acini are found to be widely dilated. It is apparent that the largest acini or cavities containing colloid are formed by the rupture of the walls of numerous smaller acini with consequent coalescence. The acinous cells are flat or cuboidal. Throughout the gland, however, will be found areas of hyperplasia where the cells are columnar and plicated, the acini small and devoid of colloid. Areas of lymphocytic infiltration are not uncommon.

Of more importance than the degenerative processes (cysts, calcification) mentioned in the preceding paragraph, are the hyperplastic changes which may take place. Nodular goiters frequently become toxic; less commonly carcinomatous changes develop in nodular goiter.

The *pathogenesis* of nodular nontoxic goiter is related to alternating periods of stimulation and involution. In that respect it may be the end result of the adolescent enlargement of endemic goiter. Clinical and experimental proof of the supposition that development of the numerous nodules throughout the gland in nodular nontoxic goiter is dependent upon frequent remission and exacerbations of the hyperplastic process (as brought about by physiologic need and strain) has been offered by Rienhoff (1926) and others. When the urgency for increased function is past, the gland involutes into a resting stage with flattened cells lining the acini, which become filled with colloid. The hyperplastic and involutional changes are largely confined to focal areas throughout the gland. These areas become circumscribed and surrounded by varying amounts of fibrous tissue which may encapsulate them; such nodules, which are often called adenomas (but perhaps erroneously), may be solitary *but usually are multiple.* However, there is one type of adenoma, viz., *fetal adenoma,* which is generally believed to be of actual neoplastic origin. Such nodules are sharply circumscribed, usually solitary, grayish or white on cut section (Fig. 4), contain very little colloid, and are of more solid consistency than the involutional type of adenoma already described. Microscopically, the acini are very small and interstitial tissue is profuse in amount, resembling, as the name implies, fetal thyroid tissue.

Clinical Manifestations. The clinical manifestations of nodular nontoxic goiter are in reality few. The patient may have an asymmetrical enlargement of the thyroid for years without any symptoms (Fig. 5). Occasionally there is a history of the presence of a symmetrical, nontoxic diffuse goiter during puberty or pregnancy for a few months before the asymmetrical nodular enlargement is noted. Although nodules or part of a lobe not infrequently descend behind the sternum or clavicle, they usually enlarge outward in the direction of least resistance, sometimes producing a tumor so unsightly as to lead the patient to request its removal for cosmetic reasons alone. As the goiter enlarges, there is an increasing tendency for the production of pressure symptoms consisting of difficulty in deglutition and breathing. The respiratory difficulty usually consists of such symptoms as coughing, a slight transitory "smothered" sensation, or attacks of actual orthopnea.

The esophageal obstruction is rarely se-

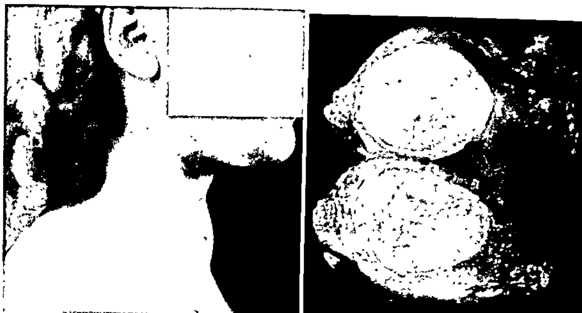


Fig. 4. Fetal adenoma. The patient, a female aged 28, first noted a nodule in the neck six years ago. Growth had been gradual. There were no manifestations of thyrotoxicosis.

vere. Occasionally, when the goiter descends downward into the mediastinum it may produce a superior caval obstruction (Fig. 6) which, however, is more common in carcinoma of the thyroid. The pressure may be caused by the thyroid encircling or compressing the trachea or esophagus, or by intrathoracic extension. Patients afflicted with nodular, nontoxic goiter over a period of years are apt to develop mild symptoms of myxedema which may require therapy with desiccated thyroid. On the other hand, thyrotoxicosis occasionally develops in the presence of nodular nontoxic goiter, particularly in the third and fourth decades of life. For some unknown reason, thyrotoxicosis of this type develops most commonly in the United States and only infrequently in goitrous regions, such as Switzerland, where nodular nontoxic goiter is prevalent.



Fig. 5. Photograph of a colored female with a nontoxic nodular goiter. The patient, aged 59, had noted a mass in the neck for 20 years; it started to grow four years ago. Recently she has had a slight choking sensation. At operation a large solitary mass, 5 cm. in diameter, was found on the right, and several small ones on the left.

Upon examination, the nodules are moderately firm except that cystic nodules are fluctuant. The mass is not movable vertically, but can be displaced to either side with the trachea. When the patient swallows, the goiter moves with the larynx. This characteristic is particularly valuable in differentiating goitrous tumors from various other masses in the neck. X-ray of the neck often shows marked deviation of the trachea.

Treatment. The treatment of nodular nontoxic goiter is preventive or surgical. The nodular as well as the diffuse type of nontoxic goiter may be prevented, at least to a great extent, by the administration of iodine in childhood and early adulthood. Furthermore, it has been shown in Switzerland that the administration of iodine to expectant mothers with nodular nontoxic goiter decreases the incidence of goiter in the children. Iodine, however, cannot be expected to cure nodular goiter, but it is valuable from a prophylactic



Fig. 6. Infrared photograph of a patient with a substernal goiter. The patient had a large nontoxic nodular goiter which extended into the superior mediastinum retrosternally. The infrared photo reveals the vast network of dilated veins which had developed as collaterals because the jugular veins were compressed by the goiter.

standpoint and to a less extent in prevention of progressive growth. It should not be administered over a long period of time to patients with nodular nontoxic goiter, because of the slight possibility of inciting the gland to hyperactivity.

Once this type of goiter develops, surgery offers the only means of eradicating it. Various indications for excision may be enumerated, the most important of which are: 1. relief of tracheal or esophageal obstruction; 2. danger of development of a toxic goiter; 3. danger of development of carcinoma; and 4. cosmetic reasons. The danger of development of carcinoma is greater than realized, as is emphasized by the fact that in a series of 448 thyroidectomies performed for nontoxic nodular goiter (in a goiter belt, Chicago between 1936 and 1952) Cole and associates (6) found carcinoma in 15.6 per cent of cases. The average incidence in seven other reports from various parts of the United States was 10.3 per cent. The solitary nodule is more dangerous than the multinodular gland as indicated by the fact that carcinoma *was found in 20.9 per cent of the solitary nod*ules, compared to 8.7 per cent of multinodular glands. This danger alone seems sufficient to justify removal of nontoxic nodular goiter, particularly if it is of the solitary nodular type. Operative treatment consists of the removal of the diseased gland. To prevent myxedema, a small portion of the most normal appearing thyroid tissue is left; if all is diseased, the entire gland is removed, but an effort is made to leave a gram or two of normal appearing gland on the less diseased side. As a rule, the posterior capsule of the gland must be left undisturbed; otherwise, tetany may develop through loss of the parathyroid glands. Particular care must be exercised in removal of large goiters lest the recurrent laryngeal nerves be injured.

DIFFUSE TOXIC GOITER

(Graves' Disease, Basedow's Disease, Exophthalmic Goiter, Hyperthyroidism)

This disease has apparently decreased markedly throughout the United States dur-

ing the past 20 years (perhaps as much as 50 per cent) as has also toxic nodular goiter.

Etiology. *It occurs more commonly in* women than men (ratio 4:1 or 5:1) and in young adult life, apparently produced by the secretion of an excessive amount of the thyroid principle, thyroxin. Some authorities are of the opinion that the etiologic factor producing the disease is not normal thyroxin, but a toxic and chemically distorted substance secreted by the diseased thyroid, but evidence supports the theory that most of the symptoms, at least, are caused by a true hypersecretion of the active principle. Up to the present time, however, there are a number of possible explanations for this excessive secretion. One is that it is presumably brought about by the stimulative action of some other endocrine gland. Since we know that the administration of certain extracts (hormones) of the pituitary gland produces hyperplasia of the thyroid gland of animals with many of the manifestations of hyperthyroidism, including exophthalmos, it would appear that the hyperplasia of toxic goiter might be due to an excessive secretion of this pituitary (thyrotropic) hormone. Although this hormone has been given to human beings on numerous occasions for various reasons, the authors are not aware of the production of hyperthyroid symptoms in any instance.

A surprisingly large percentage of patients with toxic goiter, especially of the diffuse type, date their symptoms from an acute respiratory infection from which they "did not completely recover." Less frequently, psychic shocks have been known to precipitate symptoms of toxic goiter. The factors just men*tioned should be considered contributory in* the development of toxic diffuse goiter; the exciting cause is as yet undiscovered.

Iodine Metabolism. It has long been known that the thyroid is the only organ in the body containing iodine in any significant quantity and that the iodine content of the organ is decreased in toxic goiter. Unquestionably, lack of iodine is of some importance in the development of toxic diffuse goiter, because, as in the nontoxic types just described, the disease is most prevalent in goiter belts where the iodine content of water and food is low. In both types of toxic goiter there is a negative iodine balance, i.e., more iodine is being excreted than is ingested. The blood *iodine is above* normal. It appears possible that the use of iodized salt has been the most important factor in the decreased incidence of thyrotoxicosis, but no proof is available.

Pathology. The thyroid gland in toxic diffuse goiter is friable, extremely vascular, and usually but not always enlarged. Because of the lack of colloid, the cut surface is beefy instead of glairy (Fig. 7). Microscopically, the acini are columnar instead of cuboidal and are layered as well as plicated within the lumen of the acinus (Fig. 8). If the patient has received iodine for more than a few days, the friability of the gland is lost and the normal glairy appearance of the cut surface is regained in part; furthermore, the columnar cell becomes cuboidal, the acinus larger and contains more colloid. If the disease has been present for a long time, cardiac hypertrophy may develop. The glycogen content of the liver is greatly reduced, and in fatal cases of hyperthyroidism, considerable destruction of hepatic cells may be noted microscopically. The exophthalmos, which frequently accompanies the disease, is apparently due to an edema and swelling of the retrobulbar structures including the muscles.

Clinical Manifestations. One of the first symptoms is the gradual development of a nervous irritability. The patient is restless and is reluctant to remain quiet for any length of time. Changes in personality are common and the patient becomes angered or upset emotionally without due provocation. Household cares and the demands made by children may be so irritating to women afflicted with the disease as to be almost unbearable. The *mind may* be very active, and frequently the patient plans more activities than she is capable of performing. Fatigue occurs readily and weakness is complained of. Loss of weight is a fairly constant manifestation in spite of an increased appetite. Increased sweating is usually complained of. Palpitation may be present. Intolerance to heat and tolerance to cold are commonly noted. Difficulty in sleeping is almost a universal complaint, especially if the disease is severe. In highly toxic individuals, diarrhea and occasionally vomiting occur.

The patient is apt to have spontaneous

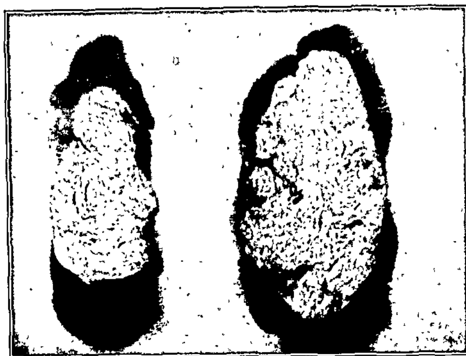


Fig. 7. Two examples of the thyroid (cut surface) of two patients with diffuse toxic goiter (Graves' disease). Each specimen has the typical beefy, somewhat homogeneous appearance, but the lobe on the left contains considerable scar tissue which is not present on the right.

remissions so that symptoms may disappear almost entirely. These remissions may last for months, but usually symptoms return and occasionally severe exacerbations occur which may be so intense as to be designated as thyroid "crises." If the disease is severe or of long duration, symptoms of cardiac disease, such as dyspnea and edema, may appear.

Examination reveals a restless patient. The thyroid gland is usually diffusely enlarged, but severe toxicity may be present without enlargement. Exophthalmos is present in many (Fig. 9), but by no means all, patients with diffuse toxic goiter. With the exophthalmos, a widening of the palpebral fissure is demonstrable (Dalrymple's sign) and diminished frequency of winking with imperfect closure of the lids during the act (Stellwag's sign). There may be a lag of the upper lid as the eye follows the finger downward (von Graefe's sign). Difficult in convergence (Moebius sign) when the patient looks at close objects may be demonstrable. A fine tremor of the fingers is noted, particularly when they are extended and abducted. The skin is warm and moist, particularly that on the palms. The face may be flushed and an anxious expression, which has been described as "frozen terror," may be noted. Tachycardia, which is increased sharply by mild exercise or other stimuli, is a reliable sign. Auricular fibrillation is only rarely present; it is more common in toxic nodular goiter. If the gland is appreciably enlarged, a thrill may be palpable over it or the vessels entering the gland, and a bruit heard by auscultation. A pulsation of the expansile type is usually palpable over the gland. The systolic blood pressure is usually elevated and the pulse pressure distinctly high.

One of the most reliable signs of toxic goiter is an increase in the *basal metabolic rate*. In severe cases this may be elevated as much as 60 to 90 per cent above normal. A rise of greater than 10 to 15 per cent above normal is considered indicative of the disease unless another cause for the elevation can be found. However, the BMR is frequently misleading because numerous diseases (leukemia, polycythemia, tuberculosis, heart disease) produce a high rate, and occasionally true hyperthyroidism may be present with an apparently normal rate. For this rea-

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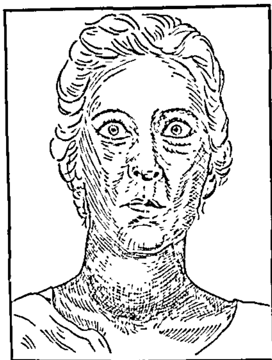


Fig. 9. Patient with appearance typical of exophthalmic goiter. Note the exophthalmos, apprehensive expression, and diffuse swelling in the neck.

Analysis of the blood for PBI (without ingestion of radioactive iodine) reveals a higher level in hyperthyroid patients than in normal people; in fact, the level is increased in an amount proportionate to the increase in metabolism. The normal PBI level is 4 to 8 μg. per 100 ml. of blood serum. Hyperthyroid persons may have levels of 9 to 12 μg. in mild cases, of 20 μg. or more in severe cases. The blood cholesterol is usually decreased in hyperthyroidism, but changes in level are not consistent enough to be of diagnostic value.

One of the most effective mechanisms in the differential diagnosis of patients with mild symptoms suggestive of hyperthyroidism is the administration of a course of iodine (10 to 15 drops of Lugol's solution per day). If the patient has thyrotoxicosis, symptoms are invariably improved within six to eight days after institution of iodine therapy. The antithyroid drugs are not very effective in this differentiation because the action in reducing thyrotoxicosis is so slow.

Treatment. The introduction of *iodine* by Plummer (1923) was a very important step in the treatment of thyrotoxicosis. However, even though the response of hyperthyroidism to iodine is rapid (with reduction in the BMR two to three points per day for 10 to 15 days), the effect nearly always wears off and after a few weeks no more beneficial effect is sustained. For this reason, iodine should be used in thyrotoxicosis only in preparation for operation, except in the occasional instance when toxicity is mild, the gland small, or the diagnosis doubtful.

In spite of the introduction of antithyroid drugs *thyroidectomy* remains a very effective method of treatment for hyperthyroidism and is perhaps the most popular. In a detailed follow-up study of 1,630 patients having thyroidectomy for hyperthyroidism, Cattell (8) noted good results in 90 to 95 per cent of cases. In 1,000 consecutive cases, the operative mortality rate was 0.2 per cent; tetany occurred in 1.5 per cent, nerve injury in 1 per cent, and recurrence in 2.4 per cent of cases.

Radioactive iodine is very effective in eliminating hyperthyroidism but it is difficult to estimate the correct dosage by the method utilized at the present time, namely, according to the estimated weight of the thyroid. At present there is disagreement as to the use of thyroidectomy or radioactive iodine in the treatment of toxic diffuse goiter. However, practically all workers in thyroid diseases would agree that radioactive iodine therapy is indicated in most patients with recurrent hyperthyroidism following thyroidectomy, in hyperthyroidism complicated by some other serious disease, in patients refusing operation, and in patients who are poor operative risks. Agreed contraindications to I^{131} therapy may be listed as follows: hyperthyroidism in children, toxic nodular goiter (especially if a solitary nodule is present), and hyperthyroidism in pregnancy or lactation. The debatable patients are those past 40 years of age with toxic diffuse goiter. In 628 hyperthyroid patients treated with I^{131}, Clark and Rule (9) report good results in 82.8 per cent; in this group, 17.2 per cent developed varying degrees of hypothyroidism. In 56.1 per cent of their patients, only one dose was required to obtain the desired result; two doses were required in 25.5 per cent; and three or more doses in the remaining 18.4 per cent. The average total dose in patients treated by Crile and Mc-



Fig. 8. Microscopical appearance of the thyroid in Graves' disease (diffuse toxic goiter). The sectio were taken from two patients with approximately the same degree of toxicity; operation after 12 days pr operative treatment with iodine. A, this section reveals the typical response of the gland to iodine therap The acinous cells in general are columnar, but not high; the acini are large and contain considerable colloi Numerous small areas are found, however, where the cells are high columnar, plicated and layered, indic ative of a hyperactive gland. B, this section exhibits practically no response to iodine. The acini are smal and contain no colloid; the cells are high, plicated and layered. Patients with glands of this type are slightl more apt to suffer recurrence of the goiter than patients whose thyroid responded to iodine.

son, other methods of diagnosing hyperthyroidism are being developed.

Measurement of the *uptake of radioactive iodine* is a very good method of differentiating hyperthyroidism from other diseases having similar symptoms. Werner and associates (7) have noted that following the oral administration of between 40 and 100 μc. of radioactive iodine (I^{131}) more iodine is taken up by the thyroid in patients with hyperthyroidism than in euthyroid (normal) individuals. The uptake of iodine at the end of 24 hours is measured with a Geiger counter placed 15 cm. from the neck. In euthyroid patients, the radioiodine uptake by the thyroid ranges between 10 and 45 per cent; in about 90 per cent of these patients the uptake will be below 35 per cent. In patients with hyperthyroidism, the uptake is above 35 per cent in 90 to 95 per cent of cases. Analysis of the level of *protein-bound iodine* (PBI) may add to accuracy of the radioactive iodine test. In hyperthyroid patients 24 hours after ingestion of I^{131}, 95 per cent or more of the radioiodine in the blood is present as PBI; in euthyroid individuals, less than 45 per cent of the iodine will be present as PBI.

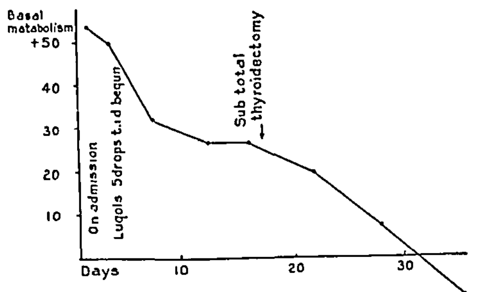


Chart 1. Basal metabolic curve in a patient with exophthalmic goiter exhibiting typical response to iodine therapy and subtotal thyroidectomy. As noted, iodine therapy will not bring the elevated basal metabolic rate to normal, but thyroidectomy will if sufficient gland is removed. Propyl-thiouracil alone will bring the rate to normal, but recurrence usually develops.

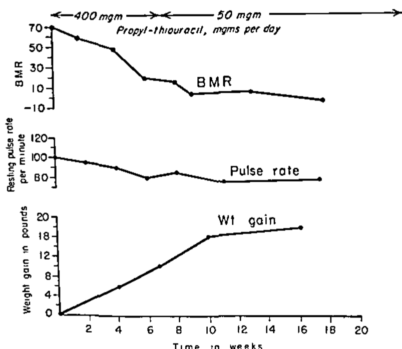


Chart 2. The treatment of thyrotoxicosis with propyl-thiouracil. The reduction of the basal metabolic rate from 70+ to 0 in nine weeks represents about the average rate of response. In this patient the resting pulse rate dropped to 80 after five or six weeks of therapy; weight gain was likewise registered early.

Cullagh (10) was 14 mc., which corresponds roughly to 100 μc. per gram of thyroid tissue. Chapman and his associates (11) recently reviewed 10 years of experiences treating hyperthyroidism with radioactive iodine. Of 400 patients treated, 8 per cent developed myxedema; 50 patients required two or more doses. The average interval between treatment and the development of a normal basal metabolic rate was two months.

Severe thyroid crisis may develop after radioactive iodine therapy but is extremely rare. Since radioautography reveals collection of radioactive iodine in innumerable pinpoint areas in thyroids of patients treated with I^{131}, it would appear that carcinoma might develop occasionally in these areas of radiation burns; however, none have been reported following this therapy. Experimentally, Doniach (12) has reported the development of an occasional cancer in the thyroid when radioactive iodine and methylthiouracil were given to rats. *X-ray therapy* has been used in the treatment of hyperthyroidism but it is much less effective than radioactive iodine.

Antithyroid drugs which block the formation of the active principle (thyroxine) of the thyroid gland may be effective in eliminating hyperthyroidism. The thiouracil compounds were originally studied and introduced by Astwood (13). Propylthiouracil and methylthiouracil are the ones being used most commonly at the present time. Another effective antithyroid drug, 1-methyl-2-mercaptoimidazole (tapazole), has been introduced more recently. The first two drugs are given in a dose of 300 to 600 mg. per day in divided doses and the latter in a dose of 15 to 60 mg. per day. Each of these drugs will, in responsive cases, reduce the BMR about one point per day. Toxic reactions (e.g., fever, urticaria, dermatitis, and neutropenia) are uncommon with each of the three drugs mentioned, occurring in about 2 per cent of cases. Insufficient dosage is a common error. Bartels and Kohn (14) have reported that doses of propylthiouracil in amounts equal to 600 to 1,000 mg. per day seldom result in significant reactions. Certainly, 300 mg. per day should be the minimum dose utilized unless sensitization is present. In many patients, if a maintenance dose (15 to 25 per cent of the therapeutic dose) is given for six months after the BMR has returned to normal, a permanent remission is obtained in a large proportion of cases. If patients are selected who have small glands, mild toxicity, and short duration of symptoms, permanent remission following prolonged therapy with antithyroid drugs may develop in 40 to 50 per cent of cases. However, since it is difficult to predict which patients will respond permanently, most physicians are using the antithyroid drugs as preparation for thyroidectomy. When they are used for this purpose, iodine should be given for 12 to 18 days before the date of operation to reduce the increased vascularity usually created by the drugs. The antithyroid drug should be omitted four or five days before thyroidectomy to prevent the rare but dangerous possibility of operating on a patient developing a reaction at this particular time. Obviously, any significant reaction to an antithyroid drug will be a contraindication for its continued use; another one may be tried cautiously. Utilization of antithyroid drugs and iodine in preparation for thyroidectomy will reduce the operative mortality rate. For example, over a 10-year period at Illinois Research Hospital before introduction of antithyroid drugs, the operative mortality rate was 0.9 per cent. In about 400 thyroidectomies for toxic diffuse and toxic nodular goiter since beginning the use of antithyroid drugs to prepare the patients, the operative mortality rate has been 0.

During treatment with antithyroid drugs or iodine, a sedative such as phenobarbital may be necessary to permit rest during the day and to insure adequate sleep. The caloric intake should be increased. While toxicity is pronounced, manual labor should be prohibited. The patient should be spared the ill effects of mental trauma. He should be encouraged to rest during the day, but complete bed rest is unwise (because of resultant muscle atrophy) unless toxicity is very severe or cardiac decompensation is present.

Excellent *postoperative* care is very important in maintaining a low or zero mortality rate following thyroidectomy. The wound should be watched closely for postoperative hemorrhage or infection. If hemorrhage develops, it usually manifests itself within 2 to 10 hours following operation. The presence



Fig. 10. Persistent exophthalmos. The patient, a Negro woman aged thirty, had exophthalmos at the time of operation two-and-one-half years ago. The exophthalmos receded slightly within a few months following operation, but during the past year has increased slightly. There is no evidence of recurrence of the hyperthyroidism. Exophthalmos usually recedes following operation, but in many patients it persists indefinitely.

thyroid tissue had been removed. However, in spite of adequate removal of glandular tissue and proper postoperative care, recurrences will occur occasionally (2 to 8 per cent of cases) and again disable the patient. Recurrent thyrotoxicosis following thyroidectomy is usually best treated with radioactive iodine.

When exophthalmos is so severe as to threaten loss of sight through ulceration of the cornea and papilledema, decompression of the orbit as suggested by Naffziger (16) may be indicated. This is particularly the case when thyroidectomy has failed to relieve exophthalmos, as is occasionally noted; in a few cases, indeed, exophthalmos may become more pronounced in spite of an adequate thyroid operation (Fig. 10). When proptosis is severe and progressive, suddenly lowering the metabolic rate by subtotal thyroidectomy may be contraindicated and slower, medical measures may be preferable. ACTH and triiodothyronine (particularly the former) are reported effective in the treatment of severe exophthalmos (McCullagh, et al., J. Clin. Endocrinol., 17:1277, 1957).

NODULAR TOXIC GOITER
(Toxic Adenoma)

For years there has been considerable discussion as to whether or not this disease was etiologically different from toxic diffuse goiter. Although the main symptoms of toxicity are similar, there are a few prominent differences, namely, that the symptoms of toxic nodular goiter are milder, and exophthalmos much less common than in toxic diffuse goiter. Moreover, the nodular disease occurs 10 to 15 years later in life than the diffuse type. In our experience with 571 patients with thyroid disease (1948 to 1956), the average age of patients with toxic diffuse goiter was 34.5 years; for toxic nodular goiter, 48.6 years; for nontoxic nodular goiter, 47.1 years; for carcinoma, 48.2 years; and for thyroiditis, 39.3 years.

Pathologically, the gland in toxic adenoma is nodular and asymmetrical. The adenomatous changes may be localized to one area (presenting as a nodule), but are usually diffused throughout the gland. Small areas of hyperplasia are almost always demonstrable at various points in the gland (Fig. 11). The

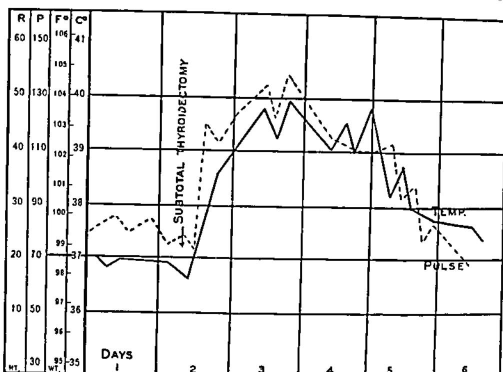


Chart 3. Temperature and pulse of patient who sustained a "crisis" following subtotal thyroidectomy. In typical cases the temperature and pulse rate begin to rise a few hours after operation, reach their maximum 24 or more hours following thyroidectomy, but recede in two or three days. Reactions of this type may be fatal, but are extremely uncommon at the present time due to preoperative use of antithyroid compounds.

of respiratory stridor demands immediate inspection of the wound. If a blood clot is causing the stridor, the wound must be opened immediately, the clot evacuated, and the bleeding controlled. If cyanosis remains after evacuation of the clot, tracheotomy may be necessary. If the stridor is due to recurrent laryngeal nerve paralysis, tracheotomy will likewise probably be necessary. If the paralysis is due to pressure from edema or mild trauma, the tube can usually be removed in a few weeks; if both nerves have been cut, the tracheotomy will probably have to be permanent unless the nerves can be successfully resutured. The operation designed by King (15) (attaching the arytenoid to the thyroid cartilage, with consequent widening of the aperture between the cords) is usually successful in restoring the airway sufficiently to allow removal of the tracheotomy tube. When considerable myocardial damage (as evidenced commonly by auricular fibrillation) is present, the need for oxygen will be more acute. Intravenous fluids must be given more slowly and in smaller quantities. Digitalis is used before operation in patients with cardiac decompensation. Its postoperative use may become necessary if pulmonary congestion or other signs of heart failure appear.

A disturbing complication of thyroidectomy is the rare occurrence of so-called thyroid "crisis" which may develop during the first day or two following operation if thyrotoxicity is severe and has not been adequately controlled by preoperative use of antithyroid drugs. This complication is characterized by extreme tachycardia, fever, marked excitability, and occasionally delirium. Treatment consists of cortisone, intravenous sodium iodide, oxygen therapy, and heavy doses of narcotics. The patient must be kept cool, with electric fans, wet towels, or an air-conditioned room in warm weather. Intravenous glucose is essential. Blood transfusions may also be indicated. It should be remembered that crisis may develop in the untreated patient. Occasionally a patient is brought to the emergency room as a new patient in a crisis.

Recurrence of thyrotoxicosis after thyroidectomy is usually indicative of an incomplete operation; i.e., that an insufficient amount of



Fig. 12. Toxic nodular goiter (toxic adenoma). Note the absence of exophthalmos. The patient aged 51 had a basal metabolic rate of 43+ on admission; after six days of iodine therapy (at the time the photograph was taken) the BMR had dropped to 29+.

in toxic nodular goiter than in toxic diffuse goiter. This may be due in part to the fact that the manifestations in the former disease are so insidious that they may exist for years before the patient is aware of symptoms; but a more logical explanation would appear to be that patients with nodular toxic goiter are older and therefore have hearts with less reserve. This myocardial damage may be uncomplicated or be associated with auricular fibrillation. In either case, shortness of breath, orthopnea, weakness, and swelling of ankles, may be complained of.

Examination reveals a nodular enlarged gland (Fig. 12) with or without a thrill and bruit. Frequently, the nodular enlargement is confined to one lobe; occasionally, the only abnormality made out in the gland is the presence of a solitary nodule. Exophthalmos or other eye signs are rarely encountered. Restlessness and irritability are usually demonstrable and a fine tremor of the fingers upon extension and abduction is always present. The palms of the hands are unusually moist. Tachycardia is noted, and if auricular fibrillation is present there will be an irregularity of the pulse with a pulse deficit. There is usually an elevation of the pulse pressure. The basal metabolic rate is elevated (15 to 50 per cent above normal), but not as high as in toxic diffuse goiter.

Treatment. Patients with toxic nodular goiter are treated similarly to those with toxic diffuse goiter. The response to various antithyroid drugs or iodine may not be as spectacular as it is in toxic diffuse goiter, but this is probably because the toxicity is not as great and morphologic changes have taken place in the gland. Surgical treatment, i.e., subtotal thyroidectomy, is especially efficacious because recurrences are seldom encountered; the resection, therefore, need not be so radical. Moreover, unless severe myocardial damage has been sustained, the symptoms of heart failure are usually relieved and the heart will be restored to a fairly normal function. The hyperthyroidism in toxic nodular goiter can be neutralized by radioactive iodine, but most clinicians prefer thyroidectomy to eliminate the nodule or nodules.

SUBSTERNAL OR RETROCLAVICULAR GOITER

Occasionally, large masses of thyroid tissue (toxic or nontoxic adenomas) are encountered behind the sternum. The mechanism of the development of a retrosternal goiter is dependent to a great extent upon the down-

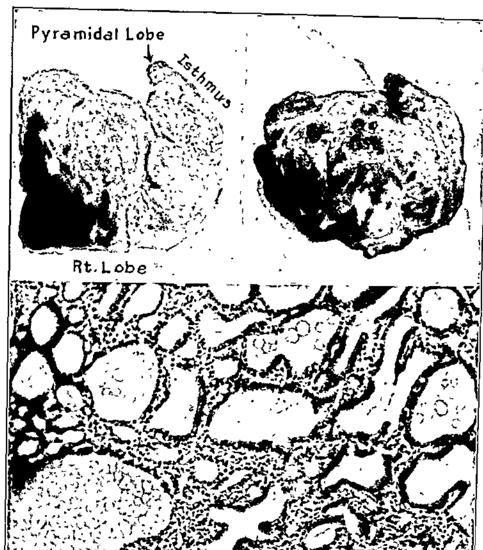


Fig. 11. Pathologic features of the thyroid in toxic nodular goiter. Above, external surface and cross section of a nodular goiter removed from a patient with toxic adenoma. The lobulations circumscribed by fibrous tissue are readily discernible in the cross section; Below, photomicrograph of tissue removed from Above. Large acini filled with colloid are numerous, but here and there are scattered areas where the acini are small, the cell tall columnar, plicated and layered, indicative of hyperactivity.

gland may encircle or compress the trachea and esophagus and produce obstructive signs. Occasionally, a large adenomatous nodule descends and is located behind the clavicle or sternum (se p. 1063). Rarely, the entire gland descends into the thorax so that nothing *more than the upper margin is palpable in the* suprasternal notch. On cut section the gland reveals globular masses of colloid-containing tissue surrounded by a fibrous capsule. Dense deposits of fibrous tissue may occur at any point throughout the gland. In addition there may be areas of beefy tissue resembling the gland seen in toxic diffuse goiter.

Clinical Manifestations. The disease is not greatly unlike toxic diffuse goiter. However, it occurs in persons 10 or 15 years older, is a milder disease, develops more insidiously, and is less often accompanied by exophthalmos or other eye signs. Crises are rarely encountered. Usually there is a history of the *presence of a nodular* enlarged thyroid for years before toxic symptoms develop. "Nervousness," weakness, and unusual susceptibility to fatigue are early *symptoms.* Irritability and emotional instability are likewise apt to be present. Difficulty in sleeping is also a fairly common complaint.

There is a greater tendency for the development of symptoms of cardiac decompensation

symptoms are present although mild hypothyroidism may be present. The thyroid is usually enlarged. Microscopic section reveals chronic inflammation, mild fibrosis, and partial to moderate loss of the alveolar architecture. The etiology is unknown, but Paine and associates (17) have shown that antibodies may be found in the blood stream, suggesting that autoimmunization against constituents of the patient's own thyroid gland may be an important etiologic factor. Many clinicians and pathologists would include these cases in the Hashimoto group.

Riedel's Struma (Ligneous Thyroiditis, Chronic Thyroiditis). Many years ago, Riedel described a rare type of disease characterized by woody hardness of the thyroid gland but associated with no known etiologic factor. Microscopically, there is a diffuse deposition of scar tissue, with a diminished number of alveoli of irregular shape and size, scattered about the gland. The gland becomes so adherent to the surrounding tissue, and the parenchyma so fibrosed that frequently it is impossible to identify the margin of glandular tissue. Mild symptoms of obstruction to the trachea and esophagus may be produced. Operation is indicated only when necessary to relieve obstruction; usually this can be accomplished by excising the isthmus.

Hashimoto's Thyroiditis. This is a chronic degenerating disease in which lymphoid infiltration and an increase in germinal centers are encountered; a variable amount of fibrosis is present. The disease is more common in females than in males and is more prevalent in mid-adult life. In a study made by Wickman and associates (17a) of 30 cases, all were females; the average age was 44. It usually affects both lobes, which gradually enlarge with mild but not marked nodularity. Symptoms are few, although most of the patients have hypothyroidism. Pain and tenderness are usually absent. Occasionally the enlargement is so marked that compression signs are produced. Except to relieve obstruction, operation is not indicated. However, it is often difficult to differentiate this disease from carcinoma, although the disease is more diffuse than anaplasia of the thyroid. In *treatment*, desiccated thyroid is fairly-specific; large doses may be indicated.

MYXEDEMA

Although a severe degree of hypothyroidism may result from the removal of too much thyroid tissue in the treatment of toxic goiter, rarely is it comparable to idiopathic myxedema. The idiopathic disease may rarely follow toxic goiter or acute and chronic thyroiditis, but in most instances there is no history of antecedent thyroid disease. The gland is small and microscopically a sharp diminution of acinar tissue with increase in amount of fibrous tissue is noted.

Clinical Manifestations. The development of clinical manifestations is so insidious that the disease may be far advanced before the patient is aware of its presence. The patient becomes mentally dull, the speech slow and "thick," as if the tongue were too large for the mouth. Constipation is rarely absent. The appetite is poor. Early in the disease the patient notes that he is very sensitive to cold and requires an unusually large amount of sleep. A gain in weight is the rule. The temperature is subnormal and the pulse rate slow. There is a masklike expression of the face, the features of which are enlarged as if swollen (Fig. 13). The skin and subcutaneous tissue over the entire body is thickened. Sweating is diminished. The hair is dry and thin. Diagnosis is readily confirmed by a basal metabolic test which will reveal a metabolic rate 20 to 40 per cent below normal. However, many patients with a low BMR do not manifest symptoms of myxedema. The blood cholesterol is high. The serum protein-bound iodine is low, and the radioactive iodine uptake is very low.

Treatment. The treatment consists almost entirely of administration of desiccated thyroid or thyroxin. It usually requires 30 to 60 grains of desiccated thyroid given over a period of several weeks to bring the patient's basal metabolism up to normal; the amount necessary for maintenance of a normal metabolism is determined by the effect on the heart rate and basal metabolic rate. Treatment should be begun with small doses (0.5 to 1 grain daily) and increased very slowly since it will take several weeks for the full effect of desiccated thyroid to become manifested. After the metabolic rate has been brought to normal, the maintenance dose (1 to 3 grains daily) is determined and is continued indefinitely.

ward growth of the enlarged gland. *It should* be emphasized that goiters of this type are at first retroclavicular in type; most of them remain so permanently. If growth of the gland persists, the mass is apt to descend, moving toward the mid-line behind the sternum. The pedicle connecting these adenomas with the thyroid itself may become greatly narrowed. On rare occasions, the retrosternal mass may have no connections with the thyroid because of its development in an aberrant thyroid or *because of atrophy of the pedicle.*

Clinical Manifestations. The clinical manifestations of substernal goiter are varied but are primarily due to the effects of pressure. Substernal goiter may be a source of considerable discomfort and be serious because of obstruction to the trachea and esophagus. There is apt to be a sensation of tightness or fullness in the upper portion of the chest, but more frequently the first symptom complained of by the patient is dyspnea or orthopnea. The dyspnea is, of course, caused by pressure on the trachea, which may progress to such an extent as to produce an audible stridor. Occasionally, mild dysphagia is present. Periodic short attacks of choking, terminating in coughing, are quite common, particularly at night while the patient is asleep. There may be dilatation of the veins of the neck or of the upper part of the chest due to compression of the thyroid or the jugular and subclavian veins. A fullness of the neck or in the suprasternal notch may or may not be visible. Deviation of the trachea, or even of the larynx from the mid-line, is an important diagnostic sign and can be demonstrated by the x-ray. X-ray, moreover, may show an abnormal shadow in the superior mediastinum which may be suggestive of a retrosternal goiter. If the substernal mass is sufficiently large, it may be demonstrable because of dullness to percussion. Differential diagnosis is frequently difficult because of the confusion with such lesions as aneurysm, thymoma, dermoid cyst, and Hodgkin's disease. The expansile type of pulsation noted fluoroscopically in an aneurysm should identify this lesion. X-ray therapy may be useful at times in establishing a diagnosis since nearly all the primary malignant tumors occurring in this region are remarkably sensitive to radiation; roentgenologically, a rapid *and marked diminution in size* will be noted following x-ray therapy in contrast to a slight or no decrease in size of a substernal goiter. Dermoid cysts will, of course, not be altered in size by radiation.

Substernal thyroids producing no symptoms need not be removed. If either obstructive or toxic symptoms are produced, excision is advisable. This may be done in most instances through an ordinary thyroid incision and the mass removed by blunt dissection *with the finger.* However, these masses must be removed with care because of the proximity of the recurrent laryngeal nerves and the danger of injury to them. When the goiter is located farther down in the mediastinum, thoracotomy will be necessary because the mass usually has a separate blood supply, arising in the mediastinum.

THYROIDITIS

Acute and Subacute Thyroiditis. *Pyogenic infection* of the thyroid is a rare disease. It is usually seen in young adults secondary to a primary focus elsewhere, such as acute pharyngitis, and is usually confined to the lower portion of one lobe. Tenderness, fever, and severe pain are usually present. Abscess formation is rare; if it does occur, incision and drainage is indicated.

More commonly, acute thyroiditis of the *nonsuppurative* type is encountered. The etiology is obscure, but the causative factor may be a virus. Histologically, a foreign body type of reaction with giant cells is noted; fibrosis is diffuse. Pain and tenderness are variable in degree; occasionally fever is present, especially at onset. Pain may be present on swallowing and may radiate to the ears. With rare exception, the involved area in the thyroid is indurated; the entire lobe is usually involved. Ultimately both lobes become involved. Cortisone is specific in relieving this condition but symptoms often return after cessation of therapy. X-ray therapy and propylthiouracil are often effective. *Operation is not indicated,* particularly since the disease is self-limited and results in no permanent damage.

Chronic Nonspecific Thyroiditis. There is a group of patients with *chronic thyroiditis* with a microscopic appearance not identifiable as Riedel's struma or Hashimoto's disease which are described below. Very few

of tumors of the thyroid arise as separate tumors and not in pre-existing nodules. In our series, only 9 per cent of patients with nontoxic nodular goiter were males, whereas 36 per cent of patients with cancer of the thyroid were males; this indicates that the danger of cancer in nodular goiter is about four times greater in males than in females.

The incidence of carcinoma of the thyroid is actually higher in childhood than in adults. In our series of children with nodules in the neck, 31.1 per cent were malignant (19). This figure is close to the 29 per cent in 145 cases assembled from the literature by Winship and Chase (20).

In our series, the average age of patients with benign nontoxic nodular goiter was 44.5 years, compared to 47.5 years for cancer. The duration of enlargement of the neck was 11.8 years in nontoxic nodular goiter but only 4.1 years in patients with cancer.

There is considerable speculation as to why carcinoma is more common in nodular goiter of children than of adults. In a study of 28 patients 18 years of age and younger, Duffy and Fitzgerald (21) found that 10 of them had had irradiation (x-ray) to the thymus between the ages of 4 and 16 months. In a series of 15 children 15 years of age and under, Clark (22) reported that all had x-ray therapy in infancy to the head, neck, or upper thorax for benign conditions in those areas. In our series (19), all of 10 children 15 years of age or younger had x-ray therapy to the head or neck between the ages of two months and six years; the dose varied between 200 r and 625 r (average 430 r). In spite of the seemingly very significant evidence presented above, many workers in this field are not convinced irradiation in infancy has a relationship to the development of carcinoma.

Pathology. Numerous classifications of carcinoma of the thyroid have been suggested; there is so little agreement that McDermott and associates (23) have offered a simplified classification in which all types are classified into one of three groups: 1. papillary; 2. follicular; and 3. undifferentiated. In their series of 179 cases they classified 50 per cent as papillary and 25 per cent in each of the other two groups. All pathologists and clinicians agree that papillary tumors are more common than any other type, and are more prevalent in young people than in elderly ones. It is well known that papillary tumors are less malignant than other types; distant metastases by way of the blood stream are uncommon although metastasis occurs early to the lymph nodes. Metastasis by the blood stream is common in the other types, particularly in the undifferentiated tumors in which it often occurs by the time the tumor has manifested itself in the neck.

CLINICAL MANIFESTATIONS. It is very difficult to differentiate benign nodular goiter from carcinoma unless the latter has metastasized. In a study of manifestations of the two lesions made recently we (19) noted that recent increase in size, cough, lack of symptoms, and feeling of pressure was slightly more common in benign nontoxic nodular goiter, whereas dysphagia was slightly more common in carcinoma. Consistency of the nodule was of no value in differentiation. Only two manifestations were of true value. Hoarseness was twice as frequent in malignancy, vocal cord paralysis was several times more common in carcinoma; it was noted in 28.8 per cent of 45 consecutive cases examined, indicating that extension of the cancer outside the thyroid capsule or metastases are fairly common by the time patients are first seen.

Treatment. Most surgeons (24, 25, 26, 27, 28) favor radical neck dissection for carcinoma of the thyroid although Crile (29) favors a conservative type of operation. Total thyroidectomy (both lobes) is favored by most surgeons recommending radical resection because removal of all normal thyroid tissue allows a greater pick-up of radioactive iodine in case that agent is chosen for supplemental therapy. Removing all normal thyroid tissue decreases the blood level of circulating thyroid hormone, thus stimulating the pituitary to secrete an increased quantity of thyroid-stimulating hormone (TSH) which causes greater concentration of the injected radioactive iodine in the metastases (30). When I^{131} was first introduced in the therapy of carcinoma of the thyroid, it was hoped that this agent would greatly improve the results. However, it was soon discovered that in 85 per cent of cases, thyroid carcinoma would not pick up enough iodine to offer therapeutic benefit (31).



Fig. 13. Characteristic facial appearance in myxedema. Note the thickening and puffiness of the eyelids and the coarseness of all the features. (From Graham. Surgical Diagnosis, Vol. 2. W. B. Saunders.)

CRETINISM

This is a disease of childhood consisting physiologically of a diminution or absence of thyroid secretion. Cretinism may be endemic, i.e., occur in localities where goiter is prevalent, or may be encountered in the sporadic form, a type in which the child is born of healthy parents and in a region where goiter is not prevalent. Cretinism is apt to develop in a child when the mother has been suffering from diffuse nontoxic goiter during pregnancy. The glandular defect is no doubt present at birth, but so long as the child is breast fed manifestations of the disease do not appear. The disease is quite common in Switzerland.

The child grows at a slower rate than average and appears stupid and unusually placid. The skin is dry. The face is large and appears bloated, and the nose is broad and flattened. The tongue, which is presumably too large for the oral cavity, protrudes through a thick-lipped mouth. Talking and walking are delayed and teeth are slow to appear. The temperature may be subnormal. The basal metabolism is below normal. If the disease is severe, dwarfism may result.

Treatment. The treatment must be instituted early in childhood if mental apathy or idiocy is to be prevented. Growth responds fairly well to the administration of desiccated thyroid, but correction of the mental dullness or idiocy is much more difficult to obtain, particularly if treatment is not started within the first year or two of life.

MALIGNANT TUMORS OF THE THYROID

There is much controversy about various phases of carcinoma of the thyroid, including incidence, diagnosis, and treatment. The incidence in nontoxic nodular goiter is reported between 5 and 17 per cent. At Illinois Research Hospital (1936 to 1953) we encountered carcinoma in 15.6 per cent of patients with nontoxic nodular goiter (18, 19). In the solitary nontoxic nodule the incidence was 20.9 per cent, compared to 8.7 per cent in multinodular nontoxic goiter. We encountered cancer in only 1.0 per cent of patients with toxic nodular goiter and in only 0.1 per cent in patients with toxic diffuse goiter. Considerable disagreement exists relative to the origin of carcinoma of the thyroid, but most workers in this field now believe the majority

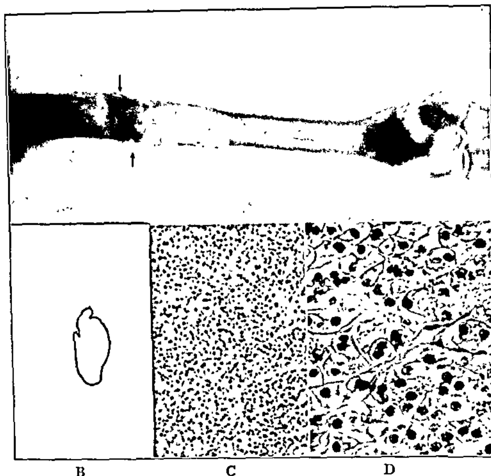


Fig. 14. Hyperparathyroidism. The patient came to the hospital because of a fracture of the humerus, sustained after only slight exertion. X-ray revealed a fracture at the site of a cyst in the shaft of the bone; numerous cysts were found in other bones. Serum calcium was 13.3 mg. per cent, but dropped to 9.8 mg. per cent the day following removal of the parathyroid tumor. A renal calculus was revealed by x-ray; it did not disappear following operation (observed for five years). A, x-ray of humerus showing cystic defects in the bone and the healed fracture (seven months after admission). X-rays three or four years later revealed deposition of calcium in these defects; B, actual size of the parathyroid tumor removed; C, low power photomicrograph; and D, high power photomicrograph of the tumor. (Courtesy, Dr. I. Y. Olch.)

ease. In hyperparathyroidism, calcium is removed from the bones and excreted through the urine. There may be diffuse demineralization of bone or cystic damage (osteitis fibrosa cystica of von Recklinghausen, Fig. 14). Renal stones are frequently formed. Although the relationship of parathyroid hyperplasia to osteitis fibrosa was probably first noted by Askanazy, the successful removal of an adenoma was not reported until 1926 by Mandl.

Clinical Manifestations. The earliest symptoms noted by the patient are apt to be muscular weakness, pains in the extremities and back, and polyuria. In a group of cases reported by Churchill and Cope (36), a surprisingly large percentage complained first of weakness, pains in the legs and thighs (particularly upon walking), backache, and difficulty in walking as produced by disturbance in gait. Occasionally a spontaneous ("pathologic") fracture through a cyst or decalcified bone is the first manifestation noted. Tumors (with or without associated tenderness) may be noted on the surface of the bones (humerus, mandible, radius, ulna). Deformity, such as kyphosis, shortening of the spine, flatfoot, and so forth, created by actual softening of the bones may occur and may therefore be readily confused with Paget's and other diseases of the bone. Lassitude, undue fatigue, and constipation are usually complained of. Polyuria and polydipsia, presumably attrib-

When administration of I^{131} is considered in addition to total thyroidectomy, Mack and associates (32) suggest that several weeks after operation I^{131} be given to locate residual functioning thyroid tissue. Studies should include 24-hour uptake and 96-hour urinary excretion of I^{131}. The body is scanned with a directional scintillation counter for extrathyroidal I^{131}. If no iodine is found, they refer the patient back at intervals of six months or one year for restudy. If and when metastases are found, a therapeutic dose of I^{131} is given. Some authorities give TSH or propylthiouracil (in large doses for months) in preparation of patients with carcinoma for therapy with I^{131}. Serious reactions from TSH have been reported. Maloof and associates (33) warn that the beneficial effect of TSH may be outweighed by the growth stimulus imparted to the metastases.

Since neither I^{131} nor x-ray therapy are very effective in the treatment of thyroid metastases, most clinicians now resort to administration of desiccated thyroid in doses equal to 3 grains per day. This therapy will cause regression of the metastases in many cases, and appears to prolong life, although cures are not to be expected from it.

If a small papillary tumor should be found in the center of a thyroid lobe without any evidence of invasion to the exterior, total lobectomy on that side may be sufficient, particularly if the patient is young; this tumor is much less invasive in young patients in whom it metastasizes primarily to lymph nodes, rarely to distant organs such as lungs and bone. However, when the tumor has invaded outward to the capsule or local metastases are present (in the absence of known distal lesions), a radical neck dissection on the affected side is indicated. Frazell and Foote (28) have demonstrated the need for a radical operation by examining the excised specimen of patients subjected to radical neck dissection in the absence of palpable metastatic nodes and finding positive nodes in 61 per cent of the specimens removed. It would appear unwise to do a local excision of the tumor when the nodes are positive in such a large percentage of cases, though not palpable.

Results. The results of treatment vary considerably in the various reports found in the literature (19). However, the majority of the reports reveal a five-year survival rate between 35 and 40 per cent. The best results are obtained in papillary tumor. A five-year survival rate of 73 per cent for this type of tumor is reported by McDermott and associates (23), but this figure is a "cumulative" rate calculated according to standard "life table" methods, excluding the expected normal death rate.

MISCELLANEOUS DISEASES OF THE THYROID

Tuberculosis, syphilis, and even actinomycosis of the thyroid occur, but they are so rare as not to justify discussion here. Primary sarcoma of the thyroid is exceedingly rare, if it occurs at all.

THE PARATHYROID GLANDS

The parathyroid glands are small glandular structures, usually four in number, measuring 3 to 6 mm. in diameter. They are usually located in the posterior capsule of the thyroid; occasionally they are found in the mediastinum. Their function in body metabolism is so important that excision of all parathyroid tissue is followed by death or severe tetany. The control of calcium metabolism is the most important function of the parathyroids. Hyperparathyroidism and tetany (hypoparathyroidism), which are the two most important diseases attributed to the parathyroids, are associated respectively with an elevation and diminution of calcium in the blood. Calcium is found in the blood serum in two forms: 1. ionizable calcium; and 2. calcium bound to protein. Ionizable calcium is the type which is altered by hyperparathyroidism and hypoparathyroidism. The symptoms are evidently dependent chiefly upon this disturbance in the blood calcium level.

HYPERPARATHYROIDISM

This disease may be produced by a generalized hyperplasia of all the parathyroid glands or by a definite adenomatous enlargement of one of the parathyroids (rarely more than one); in either case excess production of the active principle (parathormone, isolated by Hanson, 34, and Collip, 35) of the gland is the factor responsible for the dis-

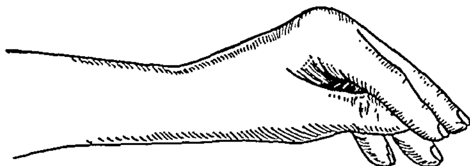


Fig. 15. Typical position of hand in parathyroid tetany.

room during induction of anesthesia and is frequently encountered in excited or hysterical persons. "Gastric tetany" caused by depletion of the acid of the stomach contents by persistent vomiting is likewise a manifestation of alkalosis.

Parathyroid tetany following subtotal thyroidectomy (for toxic goiter) is manifested usually within 24 or 48 hours after operation, but may not appear until two or three weeks later. In the latter instance, it is assumed that fibrosis resulting from excessive trauma associated with the operation is the cause of the tetany, whereas in the former instance the disease is caused by removal of the glands or severe direct trauma to them. The serum calcium drops from its normal level of about 10 mg. per 100 ml. to only 7 or even 5 mg. per 100 ml. Symptoms are rarely produced if the serum calcium is 8 or above. Perhaps the most common early manifestation is muscular weakness and twitching. This is often exemplified first by the patient's inability to grasp and lift a glass of water. Restlessness, irritability, headache, and tachycardia are common. Numbness of the hands, feet, or face and "drawing" or cramps of hands or feet may occur.

Pain associated with spasm of the muscles may be noted in the extremities and is apt to radiate downward, particularly in the arms. Diagnosis is certain when the typical carpopedal spasm, consisting of flexion at the metacarpophalangeal joints with adduction of the thumb (Fig. 15) and a similar contraction of the feet, develops. The wrist and elbow are likewise strongly flexed. Occasionally, spasm of the laryngeal muscles will be sufficient to produce respiratory difficulty. The muscular spasm of the hand may be induced by pressure interfering with the blood supply of the nerves, such as that produced by a tourniquet (Trousseau's sign). Irritability of the muscles may be so pronounced that tapping over the nerve may instigate a spasm. This is particularly true when the face is lightly tapped over the facial nerve (Chvostek's sign).

Treatment. Since the epochal discovery by Hanson (34) and Collip (35) of the active principle of the parathyroid gland, the treatment of acute parathyroid tetany is much more logical and efficient. Parathyroid extract should be given all severe cases (particularly the acute cases following thyroidectomy) and in almost every case will effect a marked improvement in the patient's symptoms. Intravenous calcium gluconate is effectual in mild cases but should not be used as the only method of treatment in the early or severe cases. If a fatal outcome can be prevented during the first few days after operation, the disease rarely terminates in death. Parathyroid extract exerts its maximum effect four to six hours after intramuscular injection and most of its calcium-elevating action is spent in 24 hours. Unfortunately, continued daily use of parathyroid extract leads in most patients to a gradually diminishing response until the hormone finally becomes ineffectual. Treatment with dihydrotachysterol (A.T.10), as reported by MacBryde (39) and others, is particularly valuable because the patient does not become resistant to its action as he frequently does to parathormone. Calcium lactate by mouth taken as a powder well stirred in water or milk, in doses of 5 grams two to four times daily, is advisable as daily therapy in the chronic cases. The addition of large doses of vitamin D to the oral calcium is effective in many chronic cases.

uted to the increased excretion of calcium and phosphorus are commonly noted.

Renal calculi are so common in this disease that hyperparathyroidism should be given diagnostic consideration in all patients with stones, particularly if they are bilateral and of the stag-horn type. Hematuria and signs of renal infection are often the most common manifestations; moreover, renal complications are the most common causes of death.

Rarely is the parathyroid tumor *palpable*. In 5 to 10 per cent of cases there will be two adenomas present, a fact the surgeon must keep in mind during operation (37).

X-ray examination of the bones is of great aid in arriving at a correct diagnosis. With few exceptions there is a generalized decalcification (osteoporosis) of the bones, which is revealed in the roentgenogram as a diffuse atrophy and moth-eaten appearance throughout the skeleton. Localized bone defects, particularly noted in the long bones and mandible, may be one of two kinds: 1. bone cysts containing thin brownish fluid; or 2. benign giant cell tumors (osteoclastomas). These cysts or tumors are usually multiple, as are shown by the x-ray. It is difficult to differentiate the cyst from the solid tumor roentgenologically, except that the solid tumors reveal more bony trabeculations through the defect. Renal calculi, containing large amounts of calcium, are commonly noted, may be bilateral and fill the entire pelvis of the kidney.

Laboratory data, particularly determination of the amount of calcium and phosphorus *in the blood, are perhaps the most reliable* means of establishing a diagnosis. Typical findings consist of the elevation of serum calcium from a normal of about 10 to a level varying from 12 to 20 or more mg. per 100 ml. of serum, and a depression of the serum phosphorus from a normal of about 4 down to 1.5 to 3.5 mg. per 100 ml. There is usually a negative calcium balance, i.e., more calcium is excreted in the urine and feces than is ingested in the food. The plasma alkaline phosphatase level, which is dependent largely upon the amount of bone change, may be elevated from a normal of 2 to 4 Bodansky units to 30 to 40.

Treatment. Excision of the tumor offers the only hope of relief. If the tumor is not readily found, it will be necessary to conduct a very thorough exploration of the neck, because the tumor, in many instances, will be located in an aberrant position. For example, in 58 adenomas found in 54 patients, Cope (36) reported that 11 were found in the anterior and five in the posterior mediastinum. Intratracheal anesthesia aids considerably in doing a thorough exploration. If possible, all the parathyroids (four or five) should be inspected since occasionally more than one will *be the seat of disease. Symptoms rapidly disappear* following removal of the tumor and the serum calcium drops to normal (within 12 to 24 hours). Following removal of the tumor, the bone lesions of the giant cell type disappear after a few months, but the bone cysts usually remain much longer. The small rarefied areas become recalcified. The renal calculi cease to enlarge, but do not disappear spontaneously. They are treated as are other kidney stones. Removal of the parathyroid tumor is occasionally followed by severe but usually transient tetany which is treated by parathyroid extract injections, intravenous or oral calcium, vitamin D, or dihydrotachysterol (A.T.10) as in tetany following accidental parathyroid injury or removal in thyroid operations. However, postoperative hypoparathyroidism tends to diminish and disappear unless the amount of parathyroid tissue remaining is grossly inadequate. If a tumor is not found, all parathyroids should be inspected for hyperplasia. Resection of two or three hyperplastic parathyroids is occasionally curative.

TETANY (Hypoparathyroidism)

The most common type of hypoparathyroidism is that seen following removal of parathyroids during thyroidectomy. However, there are other types of tetany in which the pathogenesis is not associated with the parathyroids. For example, the tetany observed frequently in children with rickets is apparently caused by avitaminosis D with failure to absorb and retain adequate amounts of calcium; it is characterized by a lowered *blood calcium level but is not* related to parathyroid deficiency. Tetany produced by overbreathing (with resultant alkalosis), as first described by Grant and Goldman (38), is occasionally seen in patients in the operating

travenous injection of sodium chloride and glucose.

Surgery finds a place in the therapy of Addison's disease through the subcutaneous implantation of pellets of desoxycorticosterone acetate. The required maintenance dose of desoxycorticosterone (DOCA) when administered by intramuscular injections in oil is first ascertained. One pellet is then implanted for each 0.5 mg. daily required by injection. The pellets weigh 75 or 125 mg. each and are usually implanted in the infrascapular region. The necessary number of pellets (usually between 2 and 10) may be inserted radially from a single small incision, a small forceps and a nasal speculum being useful for this purpose. Implantation may also be accomplished by a trocar with plunger. The absorption per pellet per day varies from 0.3 to 0.9 mg. A store of the hormone is thus established, which will last for many months. The appearance of hypertension, headaches, edema, rapid weight gain, or cardiac symptoms suggests hormone overdosage and may necessitate removal of some of the pellets.

It has been shown that elderly patients with malnutrition and other serious decrements may have severe adrenal insufficiency (42, 43), without obvious clinical evidence; such patients will respond markedly under ACTH or cortisone, which may improve operability sharply. Howland and associates (44) have emphasized that hypotension during surgery, with failure to respond with adequate blood replacement, may be the result of adrenocortical insufficiency; therapy under such circumstances should be intravenous hydrocortisone, 100 mg. given over a period of several hours.

HYPERFUNCTION OF THE ADRENALS

The clinical conditions produced by hyperadrenocorticism are variable and may be identified as Cushing's syndrome at one extreme and the adrenogenital syndrome at the other extreme. In the former condition, hyperplasia of the cortex is the abnormality usually producing the disease, whereas in the latter a tumor is usually found in the cortex.

Cushing's Syndrome. This condition, described by Cushing in 1932, was known originally as pituitary basophilism. The cause is unknown, although the manifestations are the same as those produced by prolonged administration of corticosteroids or by hyperfunction of the adrenal cortex. There is proof that the adrenal cortex is an important etiologic factor since removal of most of the hyperfunctioning adrenals results in cure. The syndrome is most frequently encountered in young females. Basophil tumors of the pituitary gland are found in about one third of the cases. Likewise, either a hyperplasia or a tumor of the adrenal cortex is found; tumors are present in about one third of the cases and often are malignant. It appears rather definite that the syndrome is mediated by the adrenal cortex.

Protein depletion is usually present because of the excessive production of glucocorticoids by the adrenal cortex, but obesity is fairly characteristic. The fat is deposited particularly over the trunk and face; the latter is rounded, giving rise to the expression "moon faced." A fat pad develops in the cervicodorsal region and has been characterized as a buffalo hump. The skin is thin, and bruises (patches of ecchymosis) are common because of increased capillary fragility; striae are usually present. Osteoporosis with decreased strength of bones is common. An insulin-resistant diabetes is usually present. Amenorrhea in females and impotence in males are common. Hirsutism develops in most female patients. At times, marked personality changes develop, with irritability or depression. Acne is common; cutaneous patches of pigmentation may occur. There is a greatly increased susceptibility to infection.

Important laboratory findings are hyperglycemia, decreased glucose tolerance test, glycosuria, eosinopenia, lymphopenia, leukocytosis, and an increased urinary corticosteroid excretion (17-hydroxycorticoids). The urinary 17-ketosteroids are usually normal or increased. Removal of the hyperplastic adrenals (leaving a few grams of tissue) results in a cure; the physical characteristics of the disease disappear after a few months, and a normal appearance is regained. If a tumor is found and removed, results will also be good.

Adrenogenital Syndrome (Virilism). The condition is presumably caused by an increased production of androgens by the adrenal cortex. If it develops in utero, pseudo-

THE ADRENALS (SUPRARENAL GLANDS)

Our knowledge of lesions of the adrenal glands progressed slowly up to a few years ago. True enough, in 1855 Addison described a clinical syndrome associated with a destructive disease of the adrenals. Many decades later (1928), Hartman and associates, and Rogoff and Stewart independently announced the prolongation of life of adrenalectomized animals by injection of adrenal cortex extracts. The discovery of ACTH and isolation of various adrenal corticoids during the past few years has allowed rapid accumulation of knowledge about diseases of the adrenal (40).

Up to the present time, chemists have isolated or identified 30 steroids from the adrenal cortex (41). Of this group, seven have demonstrable physiologic activity. They are: 17-hydroxy-11-dehydrocorticosterone (cortisone), desoxy-17-hydroxycorticosterone, 11-desoxycorticosterone, aldosterone, corticosterone, 17-hydroxycorticosterone-11-dehydrocorticosterone, and 11-desoxycorticosterone (DCA). The known adrenal cortical steroids fall into three groups according to physiologic activity: 1. those affecting primarily electrolyte and fluid balance (the desoxycorticosterones), which cause salt and water retention and promote potassium excretion; 2. those accelerating protein breakdown and increasing glucose production (the corticosterones); (cortisone, now being used in rheumatoid arthritis and in a wide variety of conditions, belongs to this group); and 3. those with androgenic activity, which are masculinizing and promote protein storage, the typical one being androsterone.

It is now recognized that adrenocortical functions are highly important in the maintenance of normal physiology. The response to stress particularly depends upon the relative integrity of the chain: central nervous system—anterior pituitary—adrenal cortex.

ADRENOCORTICAL INSUFFICIENCY

This may be acute or chronic and is characterized by: 1. a loss in sodium ion, chiefly through the urine, resulting in chloride loss, water loss, hemoconcentration and a fall in blood pressure; 2. an increase in the blood potassium, associated with a decrease in the excretion of potassium; 3. serious disturbance in carbohydrate metabolism, resulting in lowered blood sugar and a greatly reduced glycogen content of liver and muscle. Acute adrenocortical insufficiency can be produced in many species by bilateral adrenalectomy and is followed by death in a week or two. In the human being, removal or destruction of both adrenals will result in death within 24 to 72 hours. Delirium may develop, with lapse into unconsciousness with a very low blood pressure, rapid weak pulse, and hyperpyrexia. Anuria is common and muscular weakness is pronounced.

During the past several years, since bilateral adrenalectomy has been performed for the treatment of advanced cancer, acute insufficiency has been encountered occasionally when the maintenance dosage of cortisone has been omitted erroneously or is inadequate. As much as 100 to 200 mg. cortisone (by mouth) or an equal amount of hydrocortisone (by vein) over a 24-hour period, may be necessary to correct the deficiency. Acute cortical atrophy is produced by prolonged therapy with cortisone. This has a very important surgical significance if a patient needs a surgical operation while taking cortisone; if the surgeon is not aware of the prolonged cortisone therapy, and he operates without giving 200 to 300 mg. cortisone on the day of operation with reduced dosage for the next several days, the patient will usually die of shock which does not respond to blood transfusion.

Chronic adrenocortical insufficiency produces manifestations first described by Thomas Addison in 1849, and the disease is now generally given his name. The chief symptoms of Addison's disease are brownish pigmentation of the skin, weakness, loss of appetite, low blood pressure, and frequently, vomiting and diarrhea. In most cases, tuberculosis of the adrenal glands is responsible, while diffuse atrophy is the next most common cause. Rarely carcinoma, sarcoma, or adrenal hemorrhage is present. The treatment of acute severe adrenocortical insufficiency, such as occurs in the crises of Addison's disease, consists primarily of large doses of cortisone as suggested above, along with the in-

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ties occur simultaneously. Hirsutism involves the face, extremities, and trunk, although the hair on the scalp may be thin. Menses are irregular, scanty, and often absent. Libido is diminished. As the clitoris enlarges, the breasts, ovaries, and uterus decrease in size. The voice deepens, and extreme degrees of muscular development, with masculine configuration are striking.

Mixed syndromes often occur, exhibiting characteristics of virilism (masculinization) and Cushing's disease. These are usually due to adrenocortical hyperplasia, but occasionally tumors will be found. In patients with the mixed syndrome, the excretion of 17-hydroxycorticoids will usually be high.

Primary Aldosteronism. This syndrome was originally described by Conn (45). The important features are hypokalemic alkalosis, hypernatremia, paresthesia, intermittent tetany, periodic muscular weakness, paralysis, polyuria, polydipsia, and hypertension without edema. There is no increase in secretion of 17-ketosteroids or of 17-hydroxycorticoids.

No more than a dozen cases have been reported to date, but with few exceptions, a cortical tumor has been found. Biopsy of the tumor reveals a marked increase in aldosterone (45).

Within a day or two following removal of the tumor, a diuresis of sodium develops along with a retention of potassium; within a week or two the blood levels and excretion of sodium and potassium should be normal. Likewise, the blood pressure should fall to a normal level.

Tumors of the Medulla. Perhaps the most common tumor of the medulla is the neuroblastoma, which, however, has no endocrine function. These tumors are found most commonly in infancy and childhood; they are classified as sympathogoniomas, sympathoblastomas, or ganglioneuromas, depending upon the maturity of the cell. They tend to be malignant in children but are less apt to be malignant in adults.

Pheochromocytomas (Chromaffin Cell Tumors). These are endocrine tumors producing epinephrine and norepinephrine. They are usually benign; in about 10 per cent of cases they occur outside the adrenal (41), in which case they may be classified as paragangliomas. They vary greatly in size. Occasionally, when malignant they may produce functioning metastases.

The most significant symptoms are hypertension, palpitation, sweating, precordial distress, and tachycardia, which are of a paroxysmal type, fluctuating usually within a wide range. Periodic attacks of flushing and pallor of the skin caused by vasodilatation and vasoconstriction may be observed. Headache is a prominent symptom. Nausea and vomiting may be present; dyspnea and a sensation of choking may be complained of. Surgeons should always suspect pheochromocytomas in patients who develop unexplained hypertension during any operative procedure. Discovery of the cause of paroxysmal hypertension is important, since it may be surgically curable and because maintenance of hypertension may result in serious damage to the health or even death. At autopsy, pulmonary edema and cardiac hypertrophy are notable findings.

The hypertension associated with pheochromocytomas is often difficult to differentiate from essential hypertension. Adrenolytic drugs, such as regitine, dibenamine, or benzodioxane, may be helpful in differentiation as they block transmission of sympathetic nerve impulses at the myoneuric junctions and thus produce a lowering of blood pressure in patients with pheochrome tumors but not in those with essential hypertension. However, this test is by no means infallible.

Pyelography or plain roentgen films of the abdomen may reveal displacement of the upper pole of the kidney by a tumor mass. Of more value, however, is the presacral injection of oxygen as originated by Scarinci (1950). The patient is placed in the knee-chest position and a No. 18 or No. 19 needle inserted at a point equidistant from anal orifice and the tip of the coccyx in the mid-line (46). The tip of the needle is advanced between the coccyx and posterior wall of the rectum, guided by a finger in the rectum. With the aid of a three-way stopcock and 50 ml. syringe, 1,000 to 1,400 ml. of oxygen is injected over a period of 10 or 15 minutes. Less is used for children. Reactions are few and limited to a feeling of fullness or dull back pain. Immediately after injection,

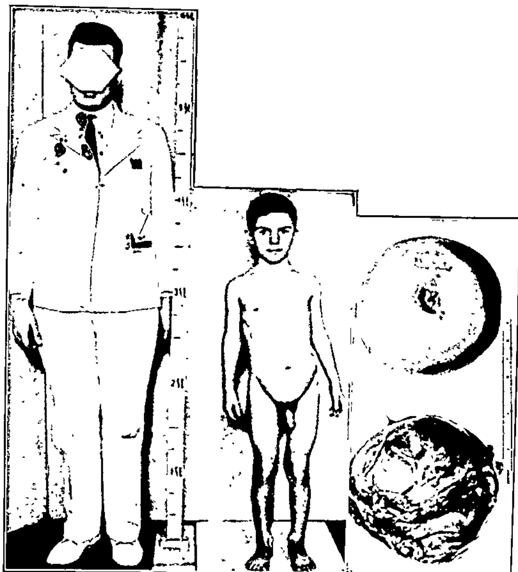


Fig. 16. Adrenogenital syndrome due to adenoma of adrenal cortex. Patient is a boy aged four years and 11 months; note the adult-size genitalia and pubic hair. A slight mustache is developing. On the right, encapsulated tumor removed successfully from the left adrenal; an apple is illustrated for comparison. As stated in the text, males are affected infrequently. (From Lisser. Transactions of the Association of American Physicians.)

hermaphroditism may be found at birth. In the preadolescent male, precocious puberty may be present; in the preadolescent and adult female, heterosexual characteristics may develop. In addition to the high androgen secretion there is a marked anabolic effect in protein metabolism; the patients are usually well developed muscularly.

Postnatal adrenal virilism encountered in females before puberty is usually due to an adrenocortical tumor. The virilism may develop shortly after birth and usually progresses rapidly. One of the most prominent characteristics in females is hypertrophy of the clitoris. Axillary and pubic hair are present as in adults.

In the male, the genitals develop rapidly, often attaining adult size at the age of five or six years (Fig. 16). Varying degrees of obesity may develop along with the increased muscle mass. The excretion of 17-ketosteroids is high, ranging from 25 to 100 mg. in 24 hours.

On most occasions, the condition is produced by a tumor; if not, diffuse hyperplasia of the cortex is present. When the patient is a female, development of masculine characteristics and suppression of feminine characteris-



Fig. 18. Photomicrograph of adenoma of pancreas which was producing typical symptoms of hypoglycemia, and was successfully removed. The cells which are similar to the so-called beta cells of the islets of Langerhans are arranged in sinuous cords. Dense connective tissue separates the cells into imperfect lobules.

tion), particularly because microscopic proof of actual hyperplasia is only rarely demonstrable.

HYPOGLYCEMIA DUE TO TUMORS OF THE ISLETS

The first case of hyperinsulinism due to a tumor of the pancreas was reported by Wilder and associates (47). This patient suffered from a carcinoma of the islets which rapidly metastasized and caused death.

Microscopically, it is difficult to determine whether a tumor of the islets is benign or malignant. However, from the clinical standpoint it is apparent that most of them are benign. The first histologic study of a series of cases, as reported by O'Leary and Womack (48), indicates that the adenomas are tumors with cells "closely allied to the beta cells of the normal islets of Langerhans." The microscopic structure of an adenoma may resemble that of a normal islet, i.e., cuboidal and pyramidal cells in columns adjacent to capillaries or rosettes of cells around a capillary (Fig. 18). Occasionally, the cells are arranged in a duct-like structure. Mitotic figures are occasionally seen. Usually the tumors are completely encapsulated, are commonly small (0.25 to 2 cm. in diameter) and are of a bluish-pink color. They are readily identified except for a slight resemblance to lymph nodes.

Clinical Manifestations. The symptoms of hypoglycemia due to tumor are dramatic but extremely variable. The most common manifestations are attacks of weakness, lassitude, and mental confusion occurring several hours after meals, particularly in the morning before breakfast. Between attacks the patient may complain of being unusually hungry and not infrequently has a craving for sweet food, such as candy. Occasionally, the patient will make the discovery that partaking of food between meals, particularly at night, will prevent the development of symptoms. The patient fatigues readily and for that reason is unable to perform much manual labor. Profuse sweating and trembling of the extremities are not uncommon. The type of mental change varies from mild confusion to attacks of unconsciousness with convulsions and is frequently erroneously diagnosed as idiopathic epilepsy, brain tumor, and so forth. The mild attacks may closely resemble the petit mal attacks of epilepsy. The patient rarely has any recollection of incidents happening during these mental disorders. Such attacks differ from epilepsy insofar as they are not accompanied by aura (unless hunger, weakness, and malaise are considered as

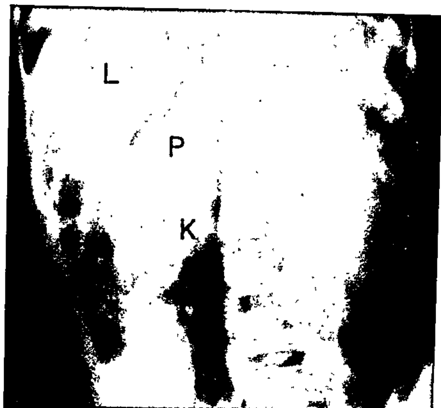


Fig. 17. Pheochromocytoma outlined by presacral injection of oxygen. The tumor is outlined by the procedure. L—liver, P—pheochromocytoma, and K—kidney.

the patient is placed supine on a tilting fluoroscopic table in a semi-erect position, and films taken. Good outlines of the kidneys and adjacent structures are usually obtained, with satisfactory demonstration of the tumor if present (Fig. 17).

Removal of the tumor is curative. However, immediately after its removal it is usually necessary to give norepinephrine for a few hours to maintain blood pressure. Cortical hormones are not necessary.

PANCREAS

In this chapter will be considered the endocrine diseases of the pancreas; the inflammatory and neoplastic lesions are discussed in Chapter 29. The former are related to the internal secretions, whereas the latter are related to the external.

The islets of Langerhans secrete insulin and are therefore presumably affected in diseases which are dependent either upon diminished secretion of insulin (diabetes, hypoinsulinism, hyperglycemia) or increased secretion (hyperinsulinism, hypoglycemia). Only the latter disease (hyperinsulinism), which may be caused by adenomas or carcinoma of the islets, will be considered here since diabetes is primarily of medical importance.

Although the most serious cases of hypoglycemia are caused by tumors (adenoma or carcinoma) of the islets, such patients comprise only a small number of those actually suffering from hypoglycemia. *Spontaneous hypoglycemia* from many causes is relatively common but that caused by true *hyperinsulinism* is quite rare. Hepatic insufficiency may be a direct cause of hypoglycemia. Deficiency in the secretion of the anterior lobe of the pituitary body may likewise result in hypoglycemia, which may be produced experimentally by removal of the anterior pituitary, but may be alleviated by pancreatectomy. Hypoglycemia may be a prominent feature in adrenal cortex deficiency (Addison's disease). In the absence of a tumor, hypoglycemia has also been attributed to a diffuse hyperplasia of the islets, but it appears more logical to explain the hypoglycemia in such cases by a mechanism similar to that just described (i.e., pituitary or adrenal hypofunc-

HYPOGLYCEMIA NOT DUE TO TUMORS OF THE ISLETS

This type of hypoglycemia is in reality much more common than that caused by adenomas. Although a few of these are due to actual hypertrophy and hyperplasia of the islets, the majority are probably due to hepatic insufficiency or to disease of the adrenal or pituitary glands. Detailed accounts of these types of hypoglycemia, including differential diagnosis and the use of insulin tolerance tests, have been discussed by MacBryde (52). Occasionally, hypoglycemia develops as an aftermath of diabetes.

Various mechanisms may result in spontaneous hypoglycemia not due to islet cell tumor. There are two possible explanations for its development, viz.: 1. insulin may be produced in excessive quantities or 2. there is a diminution below normal in insulin-resistant factors, thus making the patient more sensitive to insulin and its effects. Insulin tolerance tests should be of considerable aid in determining which mechanism is at fault. When the administration of a few units of insulin produces serious symptoms of hypoglycemia, it appears that sensitivity to in*sulin plays a role in the hypoglycemia.* The term hyperinsulinism should be applied only when production of insulin is increased.

The *clinical manifestations* of hypoglycemia of the types just mentioned are not unlike those encountered in hypoglycemia produced by adenomas of the islets. However, in the former types the symptoms are milder and mental disturbances are encountered only on rare occasions. The most common symptoms are weakness, malaise, headache, and easy fatigue. The patient usually experiences undue hunger, particularly for sweet foods.

The *treatment* of hypoglycemia not caused by tumors should at first be medical, with particular attention to the diet. Limitation of the carbohydrate in the diet to an amount barely sufficient to control symptoms, and maintenance of this diet (which should be high in its protein and fat content) over an extended period of time frequently result in recovery. Small frequent meals are employed, with a feeding at bedtime. The favorable effect exerted by the low carbohydrate diet may be explained by the diminution in the stimulus for production of insulin. The dietary measures have been discussed in detail by MacBryde (52).

Frequently, it is impossible to exclude the possibility of a pancreatic adenoma, particularly if the symptoms are severe and *not relieved by appropriate medical treatment.* In such instances, celiotomy should be performed. If no tumor is found, subtotal pancreatectomy may be indicated.

In a study of 56 cases of idiopathic hypoglycemia studied by Howard and associates (50), good results were reported in 46 per cent following subtotal pancreatectomy.

ULCEROGENIC TUMORS OF THE PANCREAS

Zollinger and associates (53) have called attention to the relationship of nonbeta islet cell adenomas (not producing insulin) of the pancreas and peptic ulceration. They have recorded data on 24 patients (their own and others encountered in the literature) which emphasize the desirability of inspecting the pancreas in every patient operated on for peptic ulcer, particularly if the patient has had a previous and unsuccessful operation *for peptic ulcer.*

PITUITARY (HYPOPHYSIS)

The pituitary gland is a small structure connected by a slender stalk to the base of the brain and isolated in a protected manner by its position within the sella turcica. The gland is composed of an anterior and a posterior lobe. The anterior lobe (pars anterior) is composed of chromophil cells with protoplasm containing granules which stain with acid or basic dyes and chromophobe cells whose protoplasm contains very few granules and stain feebly. The posterior lobe is composed of several structures, including the pars nervosa and pars tuberalis. The pars intermedia is usually considered to be a separate independent structure.

The *functions* of the hypophysis are concerned chiefly with the secretion of hormones, of which there are at least six.

1. The *adrenocorticotropic hormone* is perhaps the most important of those known at the present time. Its chief action is to stimulate the production of one (cortisone) or

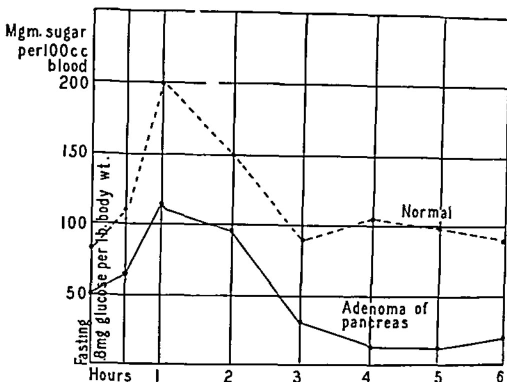


Fig. 19. Comparative sugar tolerance curves of normal individual and patient with an adenoma of the pancreas producing symptoms of hypoglycemia. The blood sugar level in the patient with the adenoma (solid line) does not rise as high as the level of the normal individual (dotted line). It usually begins at a lower fasting level and falls rapidly after ingestion of glucose to subnormal levels.

such). The intravenous administration of glucose rarely fails to relieve the patient of his mental symptoms if they are caused by a true hypoglycemia. If the attacks of hypoglycemia recur frequently or persist over a long enough time, an actual permanent mental deterioration may develop. Speech may be slurred and tremulous; occasionally, there is a hesitation in speech as if there were a mild aphasia. Rarely are any neurologic signs other than a positive Babinski present. The patient may die in an attack.

Laboratory data are of extreme value in arriving at a correct diagnosis. The fasting blood sugar is below normal and may be as low as 30 or 40 mg. (true sugar) per 100 ml. of blood, or lower during attacks; in children, the blood sugar may be as low as 20. The carbohydrate tolerance is usually increased (Fig. 19). The subcutaneous administration of epinephrine and pituitrin in patients with islet tumors usually produces only a mild elevation in the blood sugar level, but with alleviation of the symptoms mentioned above. Patients with functional hypoglycemia are more sensitive to insulin than normal; patients with islet tumors are usually less sensitive than normal.

Treatment. If there is a reasonable possibility that the hypoglycemia is caused by an adenoma of the pancreas, an operation is usually indicated (unless there are physical contraindications), because excision of adenomas of this type has been remarkably successful. The likelihood of an adenoma being the cause of the hypoglycemia is increased by exclusion of other causes by careful study, as discussed further under the next heading. Obviously, if the hypoglycemia is caused by carcinoma of the islets which has already metastasized, operation will be of no value. Fortunately, such tumors are much less frequent than benign adenomas. The pancreas is most readily exposed by making an incision through the gastrocolic omentum. Any neoplastic growths encountered should be excised. Although most tumors are located in the tail or body of the pancreas the entire organ must be inspected because of the variability in location of the tumors. A more detailed description of this disease may be found in publications elsewhere (49, 50, 51).

tary would obviously halt progression of the disease and may be followed by considerable improvement.

NEOPLASM (ADENOMAS) OF THE PITUITARY

Neoplastic growths of the pituitary may give rise to various symptoms referable to disturbance in the secretions of the gland, most of which can be classified roughly into those produced by hyperfunction or hypofunction. Most of these tumors involve primarily the anterior lobe. Manifestations of increased intracranial pressure may be produced by these tumors but are not as pronounced as those due to other brain tumors. Manifestations due to pressure on adjacent structures ("neighborhood symptoms") are often characteristic; the most important of these symptoms is disturbance in vision, because of pressure upon the optic tracts at or near the chiasm.

Chromophil Adenoma. Tumors involving the chromophil cells (those taking an acidophilic or basophilic stain readily) are usually associated with symptoms of hyperfunction. For example, an adenoma containing acidophilic cells results in certain growth manifestations, thereby substantiating the supposition that the acidophilic cells elaborate the growth hormone. If the tumor manifests itself in young people before the epiphyses close, *gigantism* results (Fig. 20). This in reality is the explanation for the famous giants in history. In most instances the disease effects the male. The eunuchoid features frequently encountered in these patients are presumably due to a deficiency of testicular hormone, the secretion of which may be inhibited by the overproduction of an anterior pituitary hormone. The bone and muscular tissue resulting from this growth stimulus appear to have a normal gross and histologic appearance, but patients afflicted with this disease do not possess a corresponding muscular strength and are very susceptible to complicating diseases, particularly infections. Surgical treatment (partial hypophysectomy) is followed by uncertain results. Testosterone propionate should be given in males and estrogens in females when hypogonadism is present.

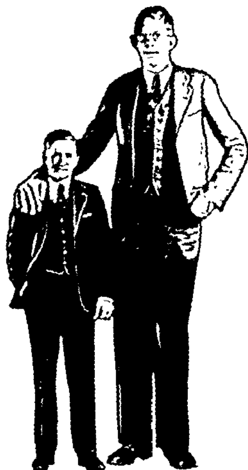


Fig. 20. Gigantism. The patient, sometimes known as the Alton giant, was 22 years old at the time of his death. He was 8 feet 9½ inches tall and weighed 491 pounds; he wore a size 36 shoe. (Courtesy, Peters Shoe Company.)

Acromegaly is produced when the adenoma manifests itself after the epiphyses have closed. It develops insidiously and slowly; the first manifestation noted by the patient is usually that larger shoes, hats, and gloves are required to fit him. The head becomes large, and the lips and tongue thickened. The lower jaw protrudes so far that the teeth of the upper and the lower jaws do not approximate (prognathism). The brow and nose are prominent. Hypertropic changes in the skin associated with wrinkling are noted, particularly about the face (Fig. 21).

In almost all instances of gigantism or acromegaly, examination by the x-ray reveals an enlargement of the sella. There is usually an accompanying erosion of the sella which is manifested by a thinning, but rarely a rough-

more hormones of the adrenal gland. ACTH and cortisone are useful in the treatment of rheumatoid arthritis (54) and of a number of other conditions, especially allergic disorders and certain eye and skin diseases; but of more importance is the tremendous influence of these hormones on numerous body functions.

2. The action of the *growth* or *somatotropic hormone* is clearly illustrated by the production of gigantism following experimental administration of an extract of the anterior lobe and by the dwarfism which follows hypophysectomy in young animals.

3. The presence of a *gonadotropic hormone* was suggested independently in 1926 and in 1927 by P. E. Smith (55) and Aschheim and Zondek (56). The latter authors noted that a gonadotropic substance similar to extracts of anterior pituitary was present in large quantities in the urine of pregnant women, a fact which they made use of in developing a test for pregnancy. In view of recent work it appears that there are two urinary gonadotropic hormones, one of which has been designated as the "follicle-stimulating hormone" and the other, the "luteinizing hormone," the latter of which may be of placental origin ("chorionic gonadotropin"). The gonadotropic hormone also acts as a *stimulus to the growth of the male organs.*

4. Experimental evidence of the *thyrotropic hormone* was discovered years ago (Loeb, Aron, in 1929), but isolation of thyrotropin (thyroid-stimulating hormone, TSH) much more recently. When given to animals, a marked hyperplasia of the thyroid results; activity of the thyroid cells is increased and I^{131} (when given to the patient) accumulates in the thyroid to a much greater degree.

5. The anterior lobe of the hypophysis also elaborates a *lactogenic hormone* (prolactine) which stimulates the secretion of milk by the mammary gland.

6. The anterior lobe of the hypophysis also secretes a *diabetogenic substance* which, when injected into hypophysectomized animals, will produce hyperglycemia and glycosuria.

The functions already discussed are performed by the anterior pituitary lobe. However, one of the first substances known to be elaborated by the hypophysis is that extractable from the posterior lobe. This is a pressor substance used to produce certain physiologic effects, such as elevation of the blood pressure, contraction of uterine muscle, and increase in intestinal peristalsis, and is commonly designated as *pituitrin*. It is not a pure hormone, however, since two (or more) products (e.g., *pitressin*, having pressor and antidiuretic properties, and *pitocin*, having oxytocic properties, stimulating uterine contraction) with separate physiologic effects have been isolated from posterior pituitary extracts.

PITUITARY INSUFFICIENCY, PITUITARY CACHEXIA, SIMMONDS' DISEASE

The symptoms of adult general pituitary insufficiency were described by Simmonds (57). If the hypofunction develops in childhood before normal stature is attained, dwarfism will result. The bones fail to grow, and ossification of the epiphyseal cartilages is delayed. Normal sexual development does not take place in either sex (sexual infantilism). The skin remains smooth and of a fine texture. There may be retardation in mental development. If the disease occurs in childhood before puberty, the male skeleton may assume a feminine appearance, with a broad pelvis and genu valgum; the fingers are apt to be *narrow and tapering*. Hair on the face, pubis and axillae is scanty or absent.

If the disease develops after puberty, there will usually be a gradual diminution of sexual activity with impotence. In women, sterility and amenorrhea are quite constantly observed. Drowsiness and somnolence are common manifestations. Polyuria and a high carbohydrate tolerance are not uncommon. The body temperature may be lowered considerably, as is also the basal metabolism.

In complete pituitary failure there is the appearance of premature senility, with loss of hair, emaciation, wrinkling of the skin, and progressive severe cachexia. The pathologic processes responsible for the development of pituitary cachexia are extremely varied and include such lesions as carcinoma, cysts, syphilis, tuberculosis, and embolism involving the anterior lobe of the pituitary.

From the surgical standpoint, the most important feature in therapy is the determination as to whether or not a tumor is present. Removal of a tumor compressing the pitui-



Fig. 23. X-ray of skull showing marked enlargement of the sella turcica in a patient aged 19, with a chromophobe adenoma of the pituitary. There is mild thinning and erosion of the posterior clinoid process. The patient had poor vision and headaches of six months' and four months' duration respectively. He also complained of a poor memory during the past few months. Visual fields revealed a *bitemporal hemianopsia*. (*Courtesy*, Dr. Ernest Sachs.)

noted by the patient until they are far advanced. Examination by perimetry will reveal variable defects but usually bitemporal hemianopsia.

The treatment of acromegaly may or may not be surgical. If the adenomatous growth is so large as to produce an impairment of vision by pressure against the optic chiasm, removal of at least a part of the tumor is indicated. Even in the absence of visual impairment, operation may be advisable because of prominent symptoms, especially headache. Resection of a large part of the tumor usually relieves the symptoms, but no improvement in the bony changes can be expected. X-ray therapy frequently will be found helpful as a substitute for operation in many cases, and should be given postoperatively, especially if symptoms recur.

Basophilic Adenoma. This type of tumor is usually nothing more than an abnormally large collection of basophilic cells and is spoken of as *pituitary basophilism*. Since this syndrome was originally described by Cushing (1932), it is now known as Cushing's disease, which has already been discussed in this chapter. Neighborhood or pressure symptoms are rarely produced by basophil adenomata, which are usually small. The clinical picture produced is that of hyperadrenocorticism.

Chromophobe Adenoma. This type of tumor is more common than the chromophil adenoma which causes acromegaly and attains a much larger size, usually breaking through upward toward the brain. For this reason "neighborhood" symptoms are more common than in acromegaly. The most frequent and significant of these neighborhood symptoms is defective vision, of the same type encountered in acromegaly, and is produced by pressure on the optic chiasm by the tumor (Fig. 23). Headaches are common. Adults are afflicted much more often than children. There is usually a diminished sexual power and desire, beginning shortly after onset of growth of the tumor, produced perhaps by pressure of the tumor on the basophilic cells. In women, amenorrhea is usually present. The patients are usually sluggish physically and a tendency toward somnolence is not uncommon. The basal metabolic rate



Fig. 21. Acromegaly. A, photograph of patient before development of the disease. B, patient is 23 years of age; three years before this photograph was taken patient noted beginning thickening of the lips and coarseness of facial features. Recently, her hands and feet have enlarged; headaches are very troublesome, and amenorrhea has been present for the past nine months. During the past several months, vision has become blurred. Visual fields reveal a bitemporal hemianopsia. See Figure 22. (Courtesy, Dr. Ernest Sachs.)

ening, of its bony wall. The hands are broad and roentgenograms reveal a thickening of the phalanges with prominent exostoses. The bones of the head are likewise thickened and massive.

Subjective symptoms may be slight. Headaches, however, are common. At first there may be an actual increase in sexual power and desire, but usually these characteristics are gradually lost. There may be secondary changes in other endocrine glands. The thyroid may be enlarged and hyperthyroidism, as evinced by an increase in the basal metabolic rate, may be present. Polyuria and mild glycosuria are not uncommon. True diabetes occurs in about 25 per cent of cases. Occasionally, the tumor may progress upward so that there is compression of the optic chiasm, thereby producing defects in the visual fields (Fig. 22). These defects are usually not

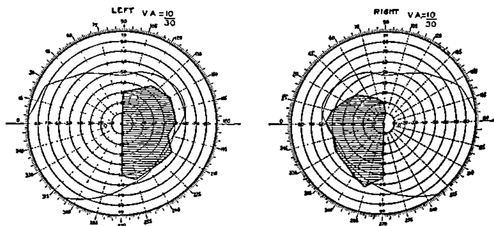


Fig. 22. Visual field revealing a bitemporal hemianopsia (same patient as in Figure 21.). The fields for a normal individual are outlined on the charts with a continuous line.

with neoplasms of the adrenal cortex but differ chiefly in the absence of obesity, hypertension, and hyperglycemia, which are apt to occur in the latter. Surgical removal will lead to complete cure. *Follicle cysts* occur because of failure of ovarian follicles to rupture and may result in prolonged absorption of large amounts of estrogenic hormones, leading to menorrhagia and metrorrhagia. When hormone therapy is unsuccessful in such patients, removal of the cyst or the whole offending ovary may prove necessary.

TESTES

Certain tumors of the testes, particularly the group called teratoma, may secrete hormones, curiously enough, which are similar to the chorionic gonadotropins produced in the placenta of the pregnant female. Most of these patients exhibit positive tests for gonadotropin. Other endocrine disturbances in the male associated with the sex hormones such as gynecomastia have been discussed elsewhere in the text. Testosterone is valuable in treating male hypogonadism. In females, it is useful in treating menorrhagia. In elderly patients, the anabolic effects of estrogens and androgens are employed in promoting protein and calcium storage. In the treatment of tumors, gonadal hormones are clinically highly useful. Estrogens inhibit cancer of the prostate. Androgens inhibit mammary cancer.

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is frequently low and the temperature subnormal. There may be a high carbohydrate tolerance. Examination reveals a soft, pale, smooth skin with loss of hair, particularly in the pubic and axillary region. In men, the hair on the face becomes finer and grows slowly so that shaving is necessary only at infrequent intervals. Many patients become obese. Affected males develop feminine characteristics, with fat pads in the breast regions and mons veneris, knock knees, tapering fingers, and soft, smooth, hairless skin. The genitals are atrophic. The x-ray usually reveals a greatly enlarged sella turcica.

With few exceptions, treatment is surgical only when the eyesight is threatened. Under this circumstance, the removal of the greater part of the tumor prevents progression of the visual defect and in many instances results in restoration of vision. Since many of the manifestations of the disease are in reality a hypofunction of the gland, surgical removal of the pituitary would obviously exert an unfavorable effect except for the relief of symptoms caused by local or general pressure of the tumor.

CYSTIC TUMORS

Several types of cysts are encountered about the pituitary, only a few of which are actually intrasellar. Most of them are suprasellar or retrosellar. They are thought to be of congenital origin, arising in "cell rests," misplaced during the neurobuccal development of the pituitary gland. A variable amount of solid tumor tissue may accompany the cyst. Many of the symptoms, as in chromophobe adenomas, are referable to pituitary hypofunction. Such cysts develop early in life and usually are recognizable in childhood by the manifestations produced. However, many are present for years without producing symptoms.

Dwarfism or stunted growth is usually the first feature noted. The genitals remain infantile. The skin is soft and pale and there is a slight tendency toward obesity. The child may develop mentally in a normal manner unless pressure manifestations occur. These pressure symptoms are extremely variable in type and may be either local or general; they are similar to those encountered in chromophobe adenomas. If the cyst encroaches upon the third ventricle, compression of vital centers in this region may lead to a fatal outcome. The foramen of Monro is occasionally blocked resulting in hydrocephalus. After the tumor has been present for many years, calcium becomes deposited in the wall of the cyst, thus making diagnosis by x-ray possible.

Unless symptoms are absent or mild, the treatment is obviously surgical. On account of the extreme variability in the location of the tumor and its attachment, operation in these cases is not only difficult but accompanied by a high mortality. After exposure of the cyst through a transfrontal approach by removing an osteoplastic flap, aspiration of its contents usually relieves the pressure symptoms but is not curative since the cyst refills.

THE GONADS

Although detailed discussion of the ovaries and testes will be found in the chapters on Gynecology and Genitourinary Diseases, respectively, certain features of these organs which are primarily of endocrine importance are considered here.

OVARIES

Certain ovarian disorders may result in endocrine abnormalities and require surgical attention. *Granulosa cell neoplasms* are composed of cells which secrete large amounts of estrogenic hormone. When they occur in young girls they produce precocious puberty with development of breasts, hair growth, and other adult secondary sex characteristics, including menstruation, either cyclic or irregular. When such tumors appear in women past the menopause, there is a return of menstruation, which is apt to be irregular and excessive. The treatment is surgical removal of the neoplasm. *Arrhenoblastoma* is an ovarian neoplasm composed of testicular type cells developing from embryonic rests within the ovary. A male type hormone similar to or identical with testosterone is secreted, and masculinizing effects are produced. Menstruation ceases, the face becomes bearded and body hair becomes more abundant and changes to the male type. The breasts atrophy and body contours become masculine. These symptoms resemble those associated

40

GYNECOLOGY

Malformations and Malpositions
Injuries of Childbirth
Infections
Neoplasms
Miscellaneous Conditions
Endocrine Disturbances
Diseases of the Vulva and Vagina

As a branch of medicine dealing with the female genital tract, gynecology has contributed significantly to the development of surgery. The first successful abdominal operation was performed for the removal of an ovarian cyst. This milestone in the history of surgery is all the more remarkable because it is dated 1809, nearly 50 years before the introduction of anesthesia and asepsis. Moreover, the scene was set in the frontier town of Danville, Kentucky. The patient was Mrs. Jane Todd Crawford, the surgeon, Dr. Ephraim McDowell, the place, a kitchen table in a small farmhouse. To be sure, it was not a true intraabdominal procedure, for the large cystic mass was merely delivered through a small incision and amputated at the stump. Nevertheless, the patient was up and about on the sixth postoperative day and lived several decades to tell her story.

Gynecology developed rapidly as a specialty, particularly through the work of J. Marion Sims, and of Howard A. Kelly. Despite its increasing limitations as a separate specialty, the female genital organs are frequently the site of disease which has general medical and specific surgical interest. This is particularly true of lesions in the pelvis, which, after all, is but a part of the general peritoneal cavity. Moreover, through the vagina one may by examination gain much information of lower abdominal disease, even when there is no pelvic lesion. The more external and obvious manifestations of gynecological disease, finally, are so common that a fundamental knowledge of them should be possessed by all practitioners whether or not they specialize in surgery, obstetrics, or gynecology. No attempt is made in this chapter to cover the field of gynecology, but only to call attention to the aspects of more general interest. The following single volume works on gynecology can be recommended: Curtis and Huffman (1), Crossen (2), Novak and Novak (3) and Meigs and Sturgis (4).

Definitions. *Normal menstruation* (catamenia, monthly flow, monthly sickness, period, menses, being "unwell") begins at puberty, which occurs usually about the fourteenth year, but varies between the eleventh and sixteenth year (5, 6). Its onset is accompanied by other manifestations of sexual maturity, both external (growth of pubic hair, breasts, and external genitalia) and internal (growth of ovaries, uterus, and vagina). Although normal menstruation varies, the average flow lasts three to five days and consists of 40 to 50 ml. of fluid blood mixed with cervical secretion and uterine debris. The length of the cycle varies somewhat between 27 and 31 days, the average being 28 days or one lunar month. Normally there is hardly any pain associated with menstruation. Changes in the breasts, external genitalia, uterus, and ovaries occur and are often noticed by the patient; other symptoms of a neurovascular nature are also present in some individuals. Menstruation occurs normally (except during pregnancy) from puberty to the *menopause* (climacteric, "change of life"). The menopause may be sudden, but is usually gradual, taking several months to years, and normally develops at about the age

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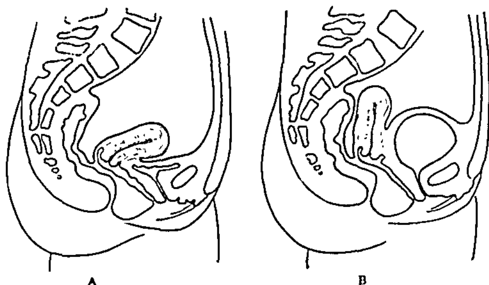


Fig. 1. Longitudinal section of the adult female pelvis. A, the normal relative positions of the various organs. B, the effect of a distended bladder.

tions, alone or in combination, and direct inspection of the cervix represent the essential minima. On special occasions other examinations are indicated. These include cystoscopic and proctoscopic study, x-ray visualization of the uterus and tubes by iodized oils, determination of their patency by injection of air, and finally, examination of urine and blood for chronic gonadotropins, which are virtually diagnostic of pregnancy (Aschheim-Zondek, Friedman, male frog tests). In some patients biopsy of cervical tissue or of endometrium (after curettage) may be necessary to arrive at a proper diagnosis.

Adult females should, if possible, be examined in the presence of a nurse or other witness whether or not the pelvis is included. *Abdominal examination* will frequently reveal much information by excluding disease outside the pelvis. However, acute pelvic inflammation often produces abdominal tenderness, rigidity, and muscle spasm which is usually bilateral but may also be located in the mid-line if an endometritis is present. A mass is rarely palpable. A full bladder is often a source of confusion and should be avoided as a possible explanation of pelvic tumor, of lower abdominal dullness, and even distention by asking the patient to void and occasionally by catherization of the bladder. Any tumor mass arising from the pelvis can be palpated abdominally after it attains a certain size (2 to 4 inches in diameter, depending on location and attachments). Thus, a pregnant uterus or large myoma can be felt as a prominent suprapubic enlargement. Ovarian cysts are often detected on examination of either or both sides of the abdomen. *Inspection of the external* genitalia will often reveal evidence of inflammation, ulcers, chancre, condyloma, cystic or other swelling, congestion, and redness about the opening of the urethra. Other abnormalities to be searched for include cystocele, rectocele, uterine prolapse, vaginal discharge, congenital malformations, and so forth. The presence of a hymen may at times be an important factor in eliminating certain types of pelvic disease.

Digital vaginal examination (Fig. 2) is ordinarily not performed during menstruation or at any time on virgins. During late pregnancy vaginal examinations are done only when necessary and with special precautions in order to avoid the danger of infection. Much information as to form and consistency of the cervix is obtainable by palpation with the tips of the fingers. The direction in which the cervix points indicates the position of the uterus; its shape and consistency is noted; tenderness on manipulation of the cervix is often significant. A soft mass or bulging behind the cervix is frequently an important indication of fluid or inflammation in the cul-de-sac. The cul-de-sac is the peri-

of 45, although great variations exist; in 68 per cent of women it occurs between the fortieth and fiftieth year. Symptoms may be absent, but are frequently severe enough to demand medical aid. Functional disturbances, such as nervousness, "hot flashes," and general irritability may hardly be classed as pathologic unless very pronounced and persistent. These functional disturbances are apt to be more severe when an *artificial menopause* has been produced by bilateral oophorectomy (excision of ovaries) and may require substitution therapy, by either oral or parenteral administration of sex hormones.

Dysmenorrhea indicates the presence of severe pain during the menstrual period. Though definitely an abnormal manifestation, it is so frequent among many otherwise normal women that the cause is often difficult to determine. In the severe cases medical aid is sought; in such patients a cause should be detected if at all possible by thorough investigation. Inflammatory, mechanical, neoplastic, neurogenic, allergic, and other factors have been described. *Amenorrhea,* or absence of menstruation, is normal before puberty, during pregnancy, and after the menopause. Otherwise, it may be due to maldevelopment, inflammatory or neoplastic disease, operations, irradiation, or ovarian dysfunction.

Oligomenorrhea, or scanty menstruation, is normal preceding menopause. *Menorrhagia* refers to an excessive amount or duration of the menstrual flow. Since individual variations are great, menorrhagia is said to be present only when a change develops which is greater than normal for the particular patient. *Metrorrhagia* indicates the presence of bleeding between menstrual periods. Although spotting may occur with ovulation, metrorrhagia is nearly always abnormal and even if slight demands investigation, particularly with the possibility of malignant disease in mind.

Normally there is a slight mucoserous discharge at the vaginal opening which keeps the parts moist. It is increased in amount during sexual excitement. It is also apt to be prominent for a few days after menstruation. When the discharge is profuse and continuous, or is of an abnormal character, it is generally an indication of inflammatory or other disease and is called *leukorrhea.* Leukorrhea usually consists of a whitish, colorless, or yellowish vaginal discharge. If brownish, the presence of blood is almost certain. Often the discharge is definitely purulent in nature or thick and mucinous. It may be profuse and cause intense irritation to the surrounding skin. *Dyspareunia* refers to painful sexual intercourse. It may be due to anatomic causes but is much more frequently due to psychic incompatibility.

Methods of Diagnosis. As a rule, gynecological diseases do not offer as much difficulty in diagnosis as many other surgical conditions, except for the group of diseases involving disturbed ovarian secretion. As in other fields, a good history and careful examination, though often neglected, are primary prerequisites for an accurate diagnosis. Special features thereof may be emphasized.

History. A good history is especially important in gynecology because the symptoms are frequently characteristic. Inquiry into the menstrual and marital history is essential and should be detailed. Urinary symptoms, such as frequency, burning, and pain on urination, are present in many gynecologic diseases. The number of complaints referable to disease of the genital organs is relatively few, but the degree of disability or the severity of the pain, especially of backache or other symptoms, may be either exaggerated or minimized. Careful evaluation of social, personal, and sexual factors is often of great significance. Care and tact are necessary in eliciting such personal information, which is often of decisive importance. It can be readily obtained by a show of interest and by the establishment of complete candor and confidence.

Examination. A routine physical examination should always include the genital tract (Fig. 1) lest the diagnosis be missed and ineffective therapy recommended. It is clear, of course, that gentleness and avoidance of pain are necessary in order to obtain as much information as possible. Judicious persistence, however, in accordance with a minimum routine, is often necessary in order to make sufficiently complete observations without which a correct diagnosis may be impossible.

Abdominal, pelvic, and rectal examina-

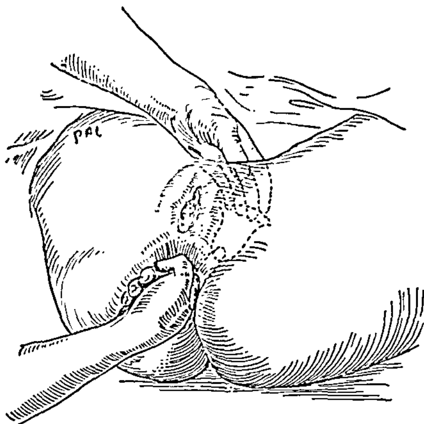


Fig. 3. Bimanual examination of the pelvis when a vaginal examination is not carried out. With the index finger in the rectum, gross abnormalities can usually be made out with a fair degree of accuracy. This method of palpating pelvic and lower abdominal structures is used in virgins and in children.

strong light to visualize the cervix (Fig. 4). The dorsal position is usually advisable. The patient is sometimes placed on her side with the knees flexed (Sims' position). In young girls and adult virgins the cervix may be visualized with a tiny speculum without injuring the hymen.

MALFORMATIONS AND MALPOSITIONS

Malformations. Defects in embryonic development produce congenital malformations of the genital tract, which though present at birth, may not produce symptoms until puberty or later during active sex life. In the external genitalia there may be enlargement of the clitoris and a rudimentary scrotum and vagina, which are characteristic of a hermaphrodite. In some cases it may be difficult to tell whether a child is male or female unless the gonads are examined histologically. Such abnormalities are extremely rare. Exstrophy of the bladder and epispadias are analogous in development to similar anomalies in the male.

Imperforate hymen produces no symptoms until puberty when menstruation begins. The uterine blood accumulates and distends the vagina (hematocolpos) which produces definite symptoms. No menstrual blood appears, but each month there occur the other manifestations of menstruation, called molimina, which consist of pelvic heaviness, engorgement of the breasts, and so forth. Since no blood can escape, the discomfort and pain in the lower abdomen becomes more and more marked as more blood accumulates, until the uterus becomes distended (hematometra) and a tender mass appears above the symphysis pubis. On examination there is no vaginal opening, but merely a distended, fluctuating membrane. Rectal examination reveals the extent of the mass. Treatment consists of adequate incision or excision of the hymen and evacuation of the old blood

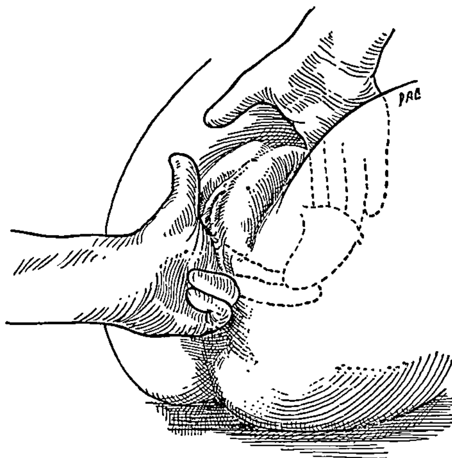


Fig. 2. Digital examination of the vagina and cervix. Note also the manner in which a bimanual palpation of the uterus, tubes and other pelvic structures may be carried out. The term pelvic examination is also applied to the bimanual technic.

toneal reflection between the posterior wall of the uterus and the anterior wall of the rectum, often called Douglas' pouch. Digital pressure over the urethra when applied from above downward may reveal on inspection a purulent discharge emerging from the urethral orifice, or from Skene's ducts.

Bimanual examination (Fig. 3) is probably the most important method of pelvic examination, because with two fingers in the vagina and the other hand on the lower abdomen, the entire pelvis can ordinarily be palpated and much information obtained. In normal sized women the tip of the examining finger reaches well up on the wall of the uterus and broad ligaments. The ovaries are usually palpable, but the tubes are not normally felt except in small, thin women. Complete relaxation of the patient is obviously necessary. For this, gentleness, cooperation, and reassurance are essential. In obese patients, satisfactory examination is often impossible. The dorsal position is usually used, but in some cases the knee-chest posture is useful. In special cases, examination under anesthesia may be indicated. The size and position of the uterus, the condition of the adnexal structure (ovaries and tubes), and the existence of masses, tenderness, and induration are especially noted.

The routine gynecologic examination should include a rectal examination. In virgins the latter is used in place of the digital vaginal examination in order to palpate the pelvis bimanually. In children especially, the entire pelvis can be palpated with great facility by bimanual rectoabdominal examination. In the later stages of pregnancy or during menstruation, a rectal replaces vaginal examination. The cervix can easily be felt through the thin rectovaginal wall.

Inspection of the cervix is very important and requires the introduction of a speculum to separate the walls of the vagina and a

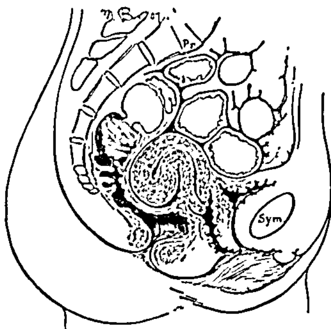


Fig. 5. Acute retroflexion of the uterus. (After Kelly.)

displacement are various and include backache, pain and discomfort in the pelvis aggravated by exercise, constipation by rectal pressure, sterility, and repeated miscarriage, particularly at the fourth month. In many cases these symptoms are due to associated lesions. Diagnosis is made by vaginal or rectal examination combined with abdominal examination (bimanual palpation).

Treatment of retrodisplacement depends on many factors, particularly its cause. In many patients in whom symptoms are not due to the malposition, no treatment may be indicated. The use of pessaries is indicated in some patients, not to correct a malposition, but to maintain the normal position which has been achieved by manual manipulation; its use, however, is contraindicated in many individuals. The operative procedures for the correction of retrodisplacement are described under treatment of childbirth injuries.

ANTEFLEXION. This is uncommon and rarely produces symptoms, except when the lumen of the uterus is kinked by the malposition. It is usually congenital. Symptoms include dysmenorrhea, especially cramplike pain during menstruation, sterility, and dyspareunia. Treatment consists of eradication of other associated lesions and of dilatation of the cervical canal to overcome the uterine stenosis. Pessaries are sometimes useful.

INJURIES OF CHILDBIRTH

Childbirth, though a normal physiologic process, is probably the most frequent cause of gynecologic disease. However, under the above heading only those will be discussed which are produced mechanically by the tearing or permanent stretching of the pelvic structures during passage of the fetus. Infections due to pregnancy are considered separately.

Relaxation and Laceration of the Perineum. The mechanical changes produced during labor vary from a simple dilatation of the vaginal opening to complete tearing of the perineum into the rectum (third degree tear). Various types of fistulas may be produced by childbirth (e.g., rectovaginal and vesicovaginal). In most patients, the external laceration is the most common injury, but is often associated with tearing of the deep pelvic muscles and fascia, particularly the levator ani, so that there is a marked weakness and relaxation of the pelvic floor (Fig. 6). Through the wide vaginal opening the posterior vaginal wall with the adjacent rectal wall may bulge (*rectocele*); the anterior wall with the adjacent urinary bladder may also protrude (*cystocele*). Frequently, the uterus itself may slip down into the dilated vagina so that the cervix presents at the out-



Fig. 4. Inspection of the cervix. Bivalve speculum in place. Sectional view, shov *speculum* and exposure of the cervix and vaginal vault by opening the blades. (From Cro Women, C. V. Mosby.)

under scrupulous aseptic precautions to avoid infection.

Atresia of the vagina (*gynatresia*) is most commonly due to an imperforate hymen (see above), but may be due to a thin septum in the canal or to a congenital absence of more or less of the entire vagina. There is in such patients an associated malformation of uterus, tubes, and ovaries, which can often be determined by rectoabdominal examination. Many instances of atresia are acquired and are really due to a stenosis produced by injury or infection. The clinical manifestations of atresia are rarely due to hematocolpos, but usually are produced because of the associated lack of development of the uterus (amenorrhea) or because of the obstacle offered to normal sexual intercourse. Treatment depends on the local conditions present and on the problem presented by the individual case. When indicated, an epithelial lined vagina may be fashioned, utilizing skin from the adjacent thigh.

Double vagina is due to the presence of a longitudinal septum which divides the vagina into two canals. Symptoms may be absent. Dyspareunia may be produced by the lesion and interference with normal labor may occur. Division of the septum is easily per-

vious symptoms of disease ar tected accidentally, especiall nancy or during x-ray study af lipiodol. When one horn is as stenosis at the cervix, hematom due to accumulation of mens

Malposition of the Uterus. of the uterus may be congenit ally acquired. Backward disp spoken of as retrodisplacemen retroversion (tipping of the backward) and retroflexion (upper part of the uterus back The clinical manifestations an these two types are so similar both be discussed under Retr

RETRODISPLACEMENT. In ment the uterus may be tippe ward that it rests on the rect common. It is due in some to relaxation of the various su ments of the cervix, in many to matory disease, in most, howe sults of childbirth and will be di that heading. It is congenital ir cent of cases. It should be emp ever, that pelvic lesions are fr tiple, retrodisplacement being a cervicitis, chronic pelvic infla lacerations of Mackenrodt's ar



Fig. 7. Complete prolapse of the uterus in a 60-year-old woman who has borne many children. (St. Louis City Hospital.)

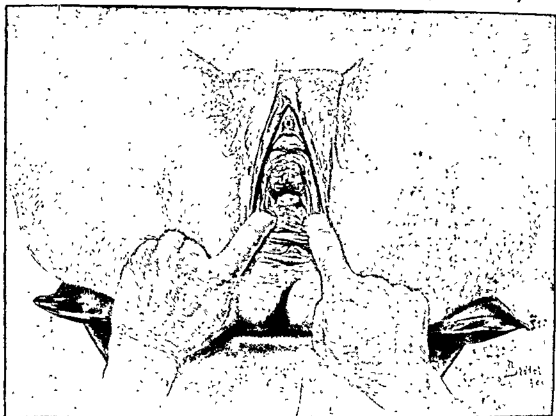
the menopause. It is called the interposition operation and is associated with the name of Watkins.

Laceration of the Cervix. A cervical laceration is of significance only when it does not heal, leading thus to erosion of the cervical mucosa, hypertrophy, cyst formation, and ulceration, all of which are manifestations of chronic infection (chronic cervicitis). Diagnosis may be suspected on palpation but is made certain only by inspection of the cervix with a vaginal speculum. Clinically, the patient may suffer only from a profuse vaginal discharge originating in the inflamed cervix. Treatment is often indicated to relieve this leukorrhea or because the lesion suggests cancer. Moreover, chronic infections of this sort are believed to encourage the development of malignant disease. Electrocoagulation or actual excision of the diseased tissue is the most effective treatment. The latter method permits microscopic study of the tissue. Simple care, notably frequent vaginal douches and topical applications to the cervix, is sometimes effective in allowing healing to occur (see Chronic Cervicitis).

Fistula. Childbirth injury may produce a communication between the rectum and vagina (rectovaginal fistula) or between the bladder or urethra and vagina (vesicovaginal fistula). The opening may, on rare occasions, be into the uterus itself or into the cervix, rather than into the vagina. Unfortunately, these lesions sometimes occur after vaginal operations or application of radium; malignant neoplasms are occasionally the cause. The distressing lack of control of feces and urine may lead to serious invalidism. Operative repair is difficult. Though silver wire is seldom used now, its introduction by Marion Sims in the middle of the last century for the operative cure of these lesions was an important step in the development of surgical technic. Each case requires its own type of operation.

INFECTIONS

Infections of the female genital tract may be classified into four groups: those due to the gonococcus, tubercle bacillus, spirochete pallida, and the pyogenic group. The first and last mentioned organisms are the most important. The manifestations of each, however, vary according to which of the several



ig. 6. Method of demonstrating relaxed vaginal outlet. The fingers are hooked in the vagina on both
s and pulled outward and backward. Note the protrusion of the anterior vaginal wall (cystocele).
er Kelly.)

(*prolapse*). If the prolapse is extreme, so the entire uterus protrudes outside the ina (Fig. 7), which is thus really turned de out, the term *procidentia* is used. ugh prolapse and procidentia are nearly ays the result of injuries sustained during dbirth, they have been known to occur in cases in women who have not borne chil-1.

LINICAL MANIFESTATIONS. Cystocele, ocele, and prolapse are accompanied by ptoms generally described by the patient sense of "bearing down" or pelvic pres-, associated with considerable fatigue r standing or walking. Backache and drag- pain are often frequent complaints, blad- symptoms, such as frequency, burning, the like, less so. In many cases, the rated cervix may become reddened and ımed and occasionally ulcerated. In se- cases (prolapse), a satisfactory position he uterus can be maintained with difficulty all.

REATMENT. Careful supervision of the ond stage of labor, the performance of a simple episiotomy, and adequate postnatal rest and care will lessen remarkably the incidence of relaxation of the pelvic floor and its various complications. Simple therapy such as the use of pessaries, rest, vaginal douches, may lead to adequate relief of symptoms. In the severe cases, however, operation is frequently indicated and may be abdominal, vaginal, or both. Abdominal operation has as its object the support of the uterus, thus preventing its descent into the vagina. The procedures consist of shortening the round or uterosacral ligaments. These suspension operations are numerous and are associated with the names of Baldy, Webster, Crossen, and a great many others. Vaginal operations are particularly indicated for rectocele and cystocele and consist of repair of the pelvic floor (colporrhaphy) through posterior (and often anterior) vaginal incisions. Repair of the lacerated cervix is often done at the same time. Fixation of the uterus may also be achieved through the vaginal route by interposing it below the bladder and is sometimes useful in older women well past

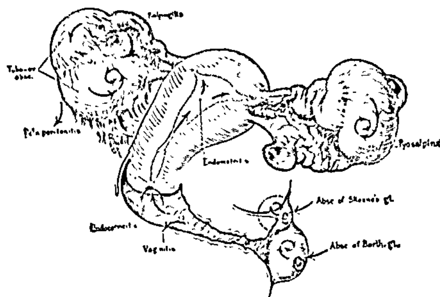


Fig. 8. Chief lesions of gonorrhea. The whorled arrows mark the common sites of infection. All lesions are those of adult women, except the vagina which is infected primarily only in childhood (juvenile vaginitis). (After Kelly.)

If a mistaken diagnosis is nevertheless made and the patient is operated upon, it is important that no operative procedures be carried out on the acutely inflamed organs in order to insure against extension of the infection. Other diseases which may offer diagnostic difficulty include tubal pregnancy, and infected dermoid cyst, and ovarian cyst with a twisted pedicle. These conditions are discussed later.

Pelvic cellulitis may be accompanied by distention, tenderness, pain in the entire abdomen, and may produce vomiting, simulating the picture of general peritonitis or intestinal obstruction. In spite of these abdominal manifestations, the absence of "toxicity" and the detection of pelvic cellulitis on palpation generally give the true clue to the diagnosis. The abdominal signs may be due to invasion of the general peritoneal cavity by the gonococcus, but are most likely due to an extension of the pelvic edema to the parietal peritoneum, or perhaps to a partial intestinal obstruction produced by adhesion of a loop of intestine to the inflammatory mass; spontaneous subsidence in a few days is the rule. On rare occasions the inflammatory mass becomes sufficiently adherent to such a loop of intestine as to produce complete occlusion.

Treatment of acute gonorrhea in the female, as in the male, has been completely revolutionized by the advent of chemotherapy, particularly penicillin (7). The sulfonamides were first used and proved fairly effective. However, the proportion of patients resistant to sulfonamide therapy has been gradually increasing ever since the introduction of these drugs. Penicillin, on the other hand, is effective against practically all strains of the gonococcus in all patients in relatively small doses, even when given in as short a period as 24 to 48 hours. In many instances 50,000 units of penicillin will completely eradicate the infection, although in most cases 100,000 to 200,000 units are necessary. This remarkable sensitivity of the gonococcus to penicillin has permitted effective treatment in many cases with a single injection. Because of the small dose required, moreover, the oral route has proved practical and relatively inexpensive. The striking and persistent sensitivity of the gonococcus to penicillin is in marked contrast to the changes in the staphylococcus. However, there are signs that even the gonococcus may be changing in that penicillin is becoming increasingly ineffective.

Complications of acute gonorrhea are generally included under the term chronic gonorrhea, although the dividing line may be difficult to draw. Complications may be en-

organs are primarily invaded. In many instances, however, all the pelvic structures are obviously the site of an infective process and the term "pelvic inflammatory disease" is used. In the acute stage, diagnosis may be easy, but when chronic infection is present, differentiation on the basis of the causative organism may be fairly difficult. Since the chronic manifestations produced by the various organisms are so similar, they will be considered together in more detail under the heading of chronic pelvic inflammation (p. 1098).

Gonorrhea. A veneral disease transmitted only by coitus (except in juvenile vaginitis), gonorrhea in the female is a prevalent disease largely because of sexual promiscuity, transmission being especially common by prostitutes. In this way innocent women are infected by their husbands who at the time of marriage consider themselves free of the disease which may have been contracted months previously. It may require six months or years after a male acquires gonorrhea before such a danger is past. Moreover, infectivity in women may last for several years. The disease in the female is serious not only because of its duration and infectivity, but also because of the frequency and ease with which it produces complete disability of the procreative and even the endocrine function of the genital organs. General disability due to chronic or recurrent infection is also common. The gonococcus, though a fragile organism, once it gains a foothold spreads rapidly, usually along the surface and between the cells of the mucous membranes; it soon reaches all the pelvic structures and sets up a severe, acute, inflammatory process. Extreme variations of severity exist. The acute manifestations usually last from one to several weeks and are followed by the chronic stage which often lasts indefinitely and is subject to recurrent exacerbations of acute nature from time to time. Fortunately the scourge of this disease has been all but eliminated by chemotherapy (see Chap. 5).

Acute Gonorrhea. Within a few days after intercourse, the disease becomes evident as a dry, burning pain in the external genitalia, followed by a yellowish vaginal discharge, frequency of, and pain and burning on, urination. These initial symptoms may be severe or may be so mild as to escape the patient's notice. The urinary symptoms are due to associated urethritis, the leukorrhea to the presence of vulvovaginitis and endocervicitis. Other lesions are frequently present or develop during the course of several days or weeks (Fig. 8). Thus, infection of the Bartholin's glands on either side of the vaginal opening often leads to abscess or cyst formation. Skene's glands, which are located on each side of the urethral meatus, are also infected and may lead to periurethral or suburethral abscesses. The inguinal lymph nodes are usually enlarged. In most patients the process sooner or later extends into the pelvis, producing an acute salpingitis or commonly an extensive inflammatory reaction of all pelvic structures. The terms pelvic cellulitis, pelvic peritonitis or acute pelvic inflammatory disease are often used to describe the extensive nature of the swelling, edema, and tenderness. Such an extension is particularly prone to develop when the infection takes place during or near the menstrual period. Of special importance to the surgeon is the fact that the lower abdominal pain, fever, and leukocytosis which accompany pelvic cellulitis may lead to a mistaken diagnosis of perforated acute appendicitis. Important in the diagnostic differentiation is the absence of toxic symptoms such as prostration, even when the fever is high. The bilateral localization of the tenderness and muscle spasm, particularly when located in the lower abdomen over the adnexal regions, is characteristic of gonorrhea. The presence of vaginal and urethral discharge is, of course, important and should be looked for. Palpation of tender masses on both sides of the pelvis on bimanual examination, and tenderness on manipulation of the cervix are nearly always noted. Occasionally, however, only one tube is affected, at least for a short time during the course of the disease. If the affected tube is on the right side, extreme difficulty in the differential diagnosis from appendicitis may be experienced. The demonstration of gonococci (intracellular, gram-negative diplococci) in stained smears of material obtained from the cervix is of obvious significance. Unlike acute appendicitis, gastrointestinal symotoms such as nausea and vomiting are generally absent.

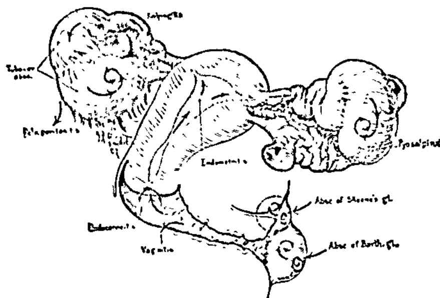


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If a mistaken diagnosis is nevertheless made and the patient is operated upon, it is important that no operative procedures be carried out on the acutely inflamed organs in order to insure against extension of the infection. Other diseases which may offer diagnostic difficulty include tubal pregnancy, and infected dermoid cyst, and ovarian cyst with a twisted pedicle. These conditions are discussed later.

Pelvic cellulitis may be accompanied by distention, tenderness, pain in the entire abdomen, and may produce vomiting, simulating the picture of general peritonitis or intestinal obstruction. In spite of these abdominal manifestations, the absence of "toxicity" and the detection of pelvic cellulitis on palpation generally give the true clue to the diagnosis. The abdominal signs may be due to invasion of the general peritoneal cavity by the gonococcus, but are most likely due to an extension of the pelvic edema to the parietal peritoneum, or perhaps to a partial intestinal obstruction produced by adhesion of a loop of intestine to the inflammatory mass; spontaneous subsidence in a few days is the rule. On rare occasions the inflammatory mass becomes sufficiently adherent to such a loop of intestine as to produce complete occlusion.

Treatment of acute gonorrhea in the female, as in the male, has been completely revolutionized by the advent of chemotherapy, particularly penicillin (7). The sulfonamides were first used and proved fairly effective. However, the proportion of patients resistant to sulfonamide therapy has been gradually increasing ever since the introduction of these drugs. Penicillin, on the other hand, is effective against practically all strains of the gonococcus in all patients in relatively small doses, even when given in as short a period as 24 to 48 hours. In many instances 50,000 units of penicillin will completely eradicate the infection, although in most cases 100,000 to 200,000 units are necessary. This remarkable sensitivity of the gonococcus to penicillin has permitted effective treatment in many cases with a single injection. Because of the small dose required, moreover, the oral route has proved practical and relatively inexpensive. The striking and persistent sensitivity of the gonococcus to penicillin is in marked contrast to the changes in the staphylococcus. However, there are signs that even the gonococcus may be changing in that penicillin is becoming increasingly ineffective.

Complications of acute gonorrhea are generally included under the term chronic gonorrhea, although the dividing line may be difficult to draw. Complications may be en-

organs are primarily invaded. In many instances, however, all the pelvic structures are obviously the site of an infective process and the term "pelvic inflammatory disease" is used. In the acute stage, diagnosis may be easy, but when chronic infection is present, differentiation on the basis of the causative organism may be fairly difficult. Since the chronic manifestations produced by the various organisms are so similar, they will be considered together in more detail under the heading of chronic pelvic inflammation (p. 1098).

Gonorrhea. A veneral disease transmitted only by coitus (except in juvenile vaginitis), gonorrhea in the female is a prevalent disease largely because of sexual promiscuity, transmission being especially common by prostitutes. In this way innocent women are infected by their husbands who at the time of marriage consider themselves free of the disease which may have been contracted months previously. It may require six months or years after a male acquires gonorrhea before such a danger is past. Moreover, infectivity in women may last for several years. The disease in the female is serious not only because of its duration and infectivity, but also because of the frequency and ease with which it produces complete disability of the procreative and even the endocrine function of the genital organs. General disability due to chronic or recurrent infection is also common. The gonococcus, though a fragile organism, once it gains a foothold spreads rapidly, usually along the surface and between the cells of the mucous membranes; it soon reaches all the pelvic structures and sets up a severe, acute, inflammatory process. Extreme variations of severity exist. The acute manifestations usually last from one to several weeks and are followed by the chronic stage which often lasts indefinitely and is subject to recurrent exacerbations of acute nature from time to time. Fortunately the scourge of this disease has been all but eliminated by chemotherapy (see Chap. 5).

Acute Gonorrhea. Within a few days after intercourse, the disease becomes evident as a dry, burning pain in the external genitalia, followed by a yellowish vaginal discharge, frequency of, and pain and burning on, urination. These initial symptoms may be severe or may be so mild as to escape the patient's notice. The urinary symptoms are due to associated urethritis, the leukorrhea to the presence of vulvovaginitis and endocervicitis. Other lesions are frequently present or develop during the course of several days or weeks (Fig. 8). Thus, infection of the Bartholin's glands on either side of the vaginal opening often leads to abscess or cyst formation. Skene's glands, which are located on each side of the urethral meatus, are also infected and may lead to periurethral or suburethral abscesses. The inguinal lymph nodes are usually enlarged. In most patients the process sooner or later extends into the pelvis, producing an acute salpingitis or commonly an extensive inflammatory reaction of all pelvic structures. The terms pelvic cellulitis, pelvic peritonitis or acute pelvic inflammatory disease are often used to describe the extensive nature of the swelling, edema, and tenderness. Such an extension is particularly prone to develop when the infection takes place during or near the menstrual period. Of special importance to the surgeon is the fact that the lower abdominal pain, fever, and leukocytosis which accompany pelvic cellulitis may lead to a mistaken diagnosis of perforated acute appendicitis. Important in the diagnostic differentiation is the absence of toxic symptoms such as prostration, even when the fever is high. The bilateral localization of the tenderness and muscle spasm, particularly when located in the lower abdomen over the adnexal regions, is characteristic of gonorrhea. The presence of vaginal and urethral discharge is, of course, important and should be looked for. Palpation of tender masses on both sides of the pelvis on bimanual examination, and tenderness on manipulation of the cervix are nearly always noted. Occasionally, however, only one tube is affected, at least for a short time during the course of the disease. If the affected tube is on the right side, extreme difficulty in the differential diagnosis from appendicitis may be experienced. The demonstration of gonococci (intracellular, gram-negative diplococci) in stained smears of material obtained from the cervix is of obvious significance. Unlike acute appendicitis, gastrointestinal symptoms such as nausea and vomiting are generally absent.

Acute Gonorrheal Vaginitis of Children. This is a clinical entity which follows inoculation of fresh gonococci on the external genitalia, usually by contact or contamination from an infected adult or another child with the disease. It is seen most commonly among children living in squalid, unhygienic, and crowded quarters. Its contagiousness makes it an especially dangerous disease in institutions caring for large numbers of little girls. The symptoms produced are usually confined to the development of a persistent, profuse, creamy, vaginal discharge which contains the organisms and often irritates the vulva and skin of the thigh. It differs from adult gonorrhea in the absence of inguinal adenitis, gonorrheal arthritis, and the rarity of salpingitis. Occasionally, however, the abdominal signs seen in adults are produced, simulating closely the picture of general peritonitis from a ruptured appendix. These abdominal manifestations subside rapidly, however, without any special treatment and are not accompanied by the severe nausea and vomiting and prostration which are so characteristic of an *E. coli* peritonitis, and therefore offer no serious diagnostic problem, provided the vaginitis is noted.

Gonorrheal vaginitis demands isolation from other children until the discharge shows an absence of the organisms on three successive examinations. Various types of douches and antiseptics have been advocated, but it is probable that simple cleanliness is all that can be achieved by such local treatment. Chemotherapy has completely eliminated most of the older methods of therapy, including the use of estrogens. The sulfonamides were first used, but penicillin is so much more effective that it is now the method of choice.

Tuberculosis. The Fallopian tubes are most frequently the primary site and though relatively rare, it is found most commonly in younger women. It is believed to originate either as a hematogenous infection or by extension from an adjacent tuberculous peritonitis. The latter lesion was present in two thirds of the 200 cases reported from the Johns Hopkins Hospital. The uterus and ovaries are secondarily involved, but the cervix is seldom, and the vagina rarely, affected.

The *clinical manifestations* develop insidiously and vary remarkably, resembling in this respect tuberculosis of the peritoneum (see Ch. 32). Abdominal pain, fever, gastrointestinal symptoms, disturbed menstruation and urination, leukorrhea, backache, and sterility have been described as important symptoms. Bimanual examination reveals only the evidences of chronic pelvic inflammation, indistinguishable from those produced by chronic gonorrhea which, when it can be excluded, especially by the history, helps in establishing the diagnosis of tuberculosis. Often, however, the diagnosis is first made at celiotomy.

Treatment consists of general and hygienic care with plenty of good food and sunshine; surgical excision of the diseased tissue may be advisable. As in the case of tuberculous peritonitis, many patients seem to improve after celiotomy alone without drainage.

Syphilis. Syphilis produces local lesions in the female external genitalia, which are similar to the primary and secondary lesions in the male, though more often occult, because they are hidden in the vagina, and hence not easily seen without careful inspection. The chancre, inguinal adenitis, mucous patch, and condyloma latum are usually similar, but may be overshadowed by a coincident gonorrheal invasion. The vulva is, however, the site of other lesions which are not syphilitic and are discussed in this chapter. Syphilitic disease of the uterus, tubes, and ovaries is rare and of no special significance, except that the cervix is reported to be frequently the site of the chancre; however, it is probably often overlooked. Syphilis is also a common cause of spontaneous abortion.

The appearance of the local lesions, the visualization of the treponema by darkfield illumination, the manifestations of the disease elsewhere, and the Wassermann or Kahn reaction make the diagnosis.

Pyogenic Infections. Pyogenic bacteria produce a great variety of pelvic disease. By excluding the gonococcus which has already been considered, nearly all of the acute infections are of puerperal origin and follow pregnancy or abortion. Chronic inflammatory disease may follow such an acute invasion; more commonly, however, the chronic lesions develop insidiously, presumably through portals of entry created or induced by childbirth injury. Other less obvious factors also

tirely absent; occasionally the infection subsides without leaving any residual pathologic changes. More commonly, the acute invasion leaves permanent and *serious disease* as an aftermath. In some patients these after-effects seem to develop insidiously with few or slight clinical manifestations at the time of invasion. Recurrent attacks of acute infection are not uncommon during the chronic stage. Other complications such as gonorrheal arthritis are discussed elsewhere.

Chronic Gonorrhea. This term is applied to such lesions as persistent infection of the cervix (endocervicitis), a localized abscess in the uterus (pyometra) and tubes (pyosalpinx), a pelvic abscess in the pouch of Douglas, a tubo-ovarian abscess, or to extensive adhesions and scar tissue in and about the various pelvic organs. Other lesions include chronic infection of Skene's and Bartholin's glands.

Bartholin's gland abscess is obvious on inspection of a rounded tender mass in the posterior portion of the labia. Pain is severe, especially on walking. It usually demands incision and drainage to relieve pain. The pus usually fails to show gonococci. *Infection of Skene's glands* generally subsides spontaneously or responds to simple local treatment. Occasionally they form tiny abscesses which may have to be incised for adequate drainage. Excision is sometimes necessary.

Endocervicitis is diagnosed with certainty only on inspection. Swelling of the cervix with ulceration and erosion of the os are typical findings. The causative organisms, however, can rarely be found in the discharge except during the acute stage. However, the presence of a tenacious, mucopurulent exudate is said to be characteristic. It presents the same therapeutic features as chronic cervicitis due to other causes and is discussed in detail separately on page 1100.

Chronic pelvic infection due to gonococcus comprises a variety of lesions, particularly chronic salpingitis and ovaritis, and is manifested by such various symptoms as bearing down pains, especially during the menstrual periods, backache, menorrhagia, dysmenorrhea, and general malaise. The diagnosis depends on thorough physical and particularly bimanual pelvic examination. On palpation, the uterus is often in a retroverted position and adnexal masses or an abscess in the cul-de-sac are demonstrable. The findings depend on the stage and extension of the disease. Great variations exist. The entire pelvis may be the site of a solid mass of granulation tissue and adhesions, in the midst of which may be an abscess. Frequently the tubes alone are involved, either as dilated structures containing pus (pyosalpinx) or in the latter stages as sterile cysts due to the disappearance of the organisms (hydrosalpinx).

Chronic pelvic infection due to gonorrhea may be of diffuse nature and can be distinguished with difficulty from the disease produced by pyogenic infections. The latter type of infection may be quite disabling, resist conservative therapy, and thereby require surgical treatment; it is described on page 1100 with similar infections not due to the gonococcus.

The *treatment* of chronic gonorrhea is at first nonoperative except for the incision and drainage of superficial abscesses as already mentioned and consists of hot douches, rest, and general hygiene. Although penicillin has revolutionized the treatment of chronic gonorrhea just as it has the acute infection, chemotherapy cannot undo damage by the gonococcus, and this includes all of the lesions included under the term "chronic pelvic inflammation" for which operation is sometimes necessary, as discussed elsewhere. Nevertheless, bacteriologic study of tissue removed in 65 patients given adequate preoperative chemotherapy revealed no growth in all but four cases. In younger women operated on, important structures are conserved, but in older women radical excision of diseased tissue is often indicated. Cul-de-sac abscesses, though not common, are usually due to secondary infection, e.g., anaerobic streptococcus and *E. coli;* they may frequently be drained by a vaginal incision posterior to the cervix.

These chronic lesions, even when the patients have no symptoms, are still a source of infection. A large percentage of prostitutes are thus permanent carriers of gonococci which remain hidden in the various occult lesions about the cervix, vagina, and urethral glands and are difficult to detect even on careful examination. This explains the constant dissemination of the disease.

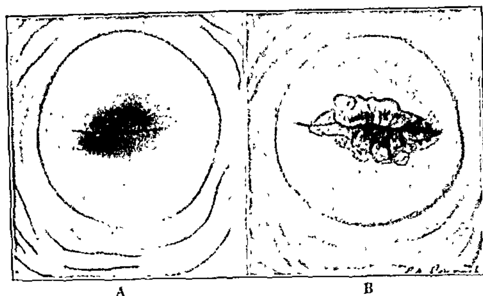


Fig. 9. Chronic cervicitis as viewed through a vaginal speculum. A, mild type, consisting of slight erosion, associated with a linear laceration. B, more severe type, consisting of definite ulceration and cyst formation. This type, if present for years, is believed to be a lesion which is a precursor of cancer.

CHRONIC PELVIC INFLAMMATORY DISEASE (CHRONIC PELVIC CELLULITIS, PARAMETRITIS). A specific diagnosis is difficult because of the variety of infective agents (gonococcus, tuberculosis, puerperal infections) and because other lesions are often confused with it, such as myoma of the uterus and other tumors, tubal pregnancy, and ovarian cysts. Moreover, the pathology is variable and may be confined to a diffuse fibrosis or induration, or it may consist of the presence of one or more abscesses, small or large, located in various parts of the pelvis. Malposition of the uterus is often associated. On pelvic examination, induration or extreme hardness is felt very low in the pelvis, especially on either side of the cervix. A mass may be made out and, if tender and fluctuant, suggests an abscess.

The *clinical manifestations* as well as the physical findings often give no clue as to the etiology. Such nonspecific symptoms as backache, pain in the lower abdomen, tenderness in the pelvis, and various menstrual disturbances are common.

Leukorrhea alone may bring the patient to the physician. The disability, however, may occasionally be severe enough to provoke rest in bed. Frequently, no symptoms are produced except that the patient comes to the doctor because of sterility. In other patients, evidence of chronic, long standing infection may be present, such as fever, emaciation, and anemia.

Differential diagnosis is of special importance in order to carry out effective therapy. There are seven diseases (modified from Crossen, 2) to be considered. 1. *Chronic endometritis* is rare except when due to polyps, abortion, functional bleeding, or malignancy. It is a cause of leukorrhea (when the cervix is normal), and of vaginal bleeding; it can often be diagnosed only by the examination of endometrial tissue obtained by curettage. The lesion is sometimes due to abnormal hyperplasia (fungous or polypoid endometritis). Treatment consists of removal of the primary lesion. 2. *Myoma of the uterus* produces symptoms of gradual onset; there is no fever or history of pelvic peritonitis; the mass is hard and not tender or fixed, and is a part of the uterus (see p. 1103). 3. *Tuberculosis* is of gradual onset and there is no history of acute infection. The presence of tuberculosis elsewhere as well as general malaise and loss of weight is often suggestive. Encysted ascites is sometimes detected. 4. *Syphilis,* though rare, is suspected when syphilis is present elsewhere and the Wassermann reaction is positive. Occasionally, gonorrhea may also be present in these patients as an associated disease. 5. *Ovarian and broad ligament tu-*

play a role; in general, therefore, chronic pyogenic infection offers a difficult problem in diagnosis, in determination of the causative organism as well as the portal of entry.

ACUTE INFECTIONS. Puerperal infections may follow either a presumably normal delivery or a criminal abortion. Before the days of chemotherapy this serious group of acute pelvic infections annually caused thousands of fatalities. They were of two types, exogenous and endogenous. The former were due to contamination, usually of *E. coli*, streptococci, and staphylococci, and represent infections which should be almost entirely avoidable. Endogenous infection, due to various types of anaerobic streptococci (Schottmueller) which the patient harbors herself, presented a more difficult problem. Even when the infection was not fatal it often resulted in complications which were the cause of serious and persistent disability. Puerperal infections are also of surgical interest because of their historical association with the development of aseptic technic (see Ch. 4) and are just as clearly due to contamination as in the time of Oliver Wendell Holmes. While the principles of aseptic technic in the prevention of infection are still basic, it must be admitted serious puerperal infection has virtually disappeared only since the advent of routine modern chemotherapy in all patients with significant postpartum fever.

When a criminal abortion leads to general septicemia, acute abdominal signs and symptoms are often mistaken for a general peritonitis from a ruptured appendix, especially since a correct history is often difficult to obtain. A foul bloody discharge, the profound toxic appearance of the patient, and evidence of extensive pelvic inflammation on bimanual palpation are usually sufficient to make the diagnosis.

CHRONIC PYOGENIC INFECTION. Even if gonorrhea is excluded, chronic infections of the genital tract in general are frequent. Although acute pelvic cellulitis of puerperal origin is often responsible, many cases result from obstetrical injury which has permitted an insidious secondary invasion. In many patients the source of infection may be difficult to determine and is entirely unrelated to puerperal infection. Invasion of this type may be classified into infection of the cervix (chronic cervicitis) and infection of the pelvis (chronic pelvic inflammatory disease).

Chronic cervicitis (*endocervicitis*) produces symptoms largely of leukorrhea which may become irritating to the patient (Fig. 9). Such symptoms as backache, dragging pelvic discomfort, and pain over the sacrum are frequently due to associated lesions, particularly chronic pelvic inflammation and various pelvic lacerations and uterine malpositions which have already been described. Regardless, however, of whether the disease has been produced by gonorrhea, unhealed lacerations, or other causes, the symptomatology, pathology, and treatment are similar.

Through the vaginal speculum the hypertrophies, erosions, or ulcerations may be shown with many cysts and polyps, particularly in the canal from which a mucopurulent discharge appears. Various terms, such as cervical catarrh, glandular endocervicitis, cystic disease, inflammatory hypertrophy, are used to describe the lesion. Chronic cervicitis especially in older women may be a precursor of cancer. The chronicity is due to the presence of the organisms deep within the mucous glands adjacent to the cervical canal and of obstruction to the glands producing cysts. In a few women, polyps are present in the cervical canal and become infected, leading to exudation which contributes to the chronic irritation. Chronic purulent discharge from deeply infected cysts also plays a similar role. Only rarely is bacteriologic study of any value since secondary invaders nearly always predominate. Even if the primary organism is present, mixed flora is therefore found.

Treatment in chronic cervicitis depends on the age of the patient and the amount of discharge and the presence of other disease. The various methods may be listed as: 1. vaginal douches, cleanliness and topical applications; 2. electrocoagulation of the diseased tissue; or 3. excision and plastic repair of the cervical canal which contains the cystic infected glands and crypts (trachelorrhaphy). One type of operation, conical excision, is usually associated with the name of Sturmdorf. More recently, excision (conization) is carried out with a cautery wire so that bleeding is minimized, and yet the coagulation is so slight that sufficient tissue is obtained for microscopic study.

months or years, and even then only when the mass is clearly the source of symptoms which have not been relieved by other care. On the other hand, if the infection has followed a pregnancy, it is often due to the streptococcus, which in general contraindicates abdominal operation, even after the lapse of some time, unless specific lesions are mechanically producing the symptoms. Careful history and study of each patient should be carried out to determine the etiologic organism if possible. In any case, the avoidance of radical pelvic operations should be emphasized, particularly in younger women in whom sufficient ovarian tissue should be preserved to maintain its endocrine function, and enough of the Fallopian tube to make pregnancy possible. For the same reason the uterus should not be removed unless absolutely necessary. Promiscuous pelvic evisceration, particularly in younger women, is to be seriously condemned; plastic operations are often sufficient to relieve symptoms. In most cases, nonoperative care is frequently satisfactory.

NEOPLASMS

Both benign and malignant tumors occur in the female genital organs, and are best classified as they affect the various organs, uterus, ovaries, Fallopian tubes, and vagina. Detailed discussion of pelvic tumors may be found in the texts already referred to.

UTERUS

Myoma is by far the most common benign tumor. (Endometriosis is described here since it may start in the uterus.) The malignant tumors are carcinoma, which is common, and chorioepithelioma and sarcoma, both of which are rare.

Myoma (Fibroid Tumor, Fibromyoma). This is the most common pelvic tumor (Fig. 11). Essentially a benign neoplasm of the smooth muscle of the uterine wall, fibromyoma nearly always contains a variable amount of fibrous tissue; hence its name. In some patients endometrial cells are found scattered through the tumor; the term adenomyoma is used in these cases (see also Endometriosis).

Myomas may be single or multiple; they are nearly always encapsulated and can be easily shelled out when in the uterine wall, where they begin their growth as interstitial or intramural myoma. Their growth is slow and progressive, requiring years before they reach an appreciable size; 20 to 30 per cent grow toward the peritoneal surface and are called subperitoneal myomas. If they grow out still farther, they may become pedunculated or even attached to other structures and lose their connection with the uterus (wandering or parasitic myoma). If the tumor grows inward toward the lumen of the uterus, it is called a submucous myoma, which also may become pedunculated; if it pushes into the broad ligament, it becomes an intraligamentary tumor. Only rarely is myoma located in the cervix. Secondary changes which may occur in large myomas are necrosis, due to inadequate blood supply, hyaline changes and liquefaction, hemorrhage into the mass, sarcomatous degeneration, infection, suppuration, and calcification. Associated effects are due to attachments with or pressure on neighboring structures. In this way the ureters may be occluded, thereby producing urinary obstruction; the vessels or nerves to the lower legs may be compressed, producing various effects; attachment by adhesions may lead to intestinal obstruction.

Clinical manifestations may be absent when the tumor is small or may be confined to menorrhagia, dysmenorrhea, and slight leukorrhea. However, bleeding may be profuse and lead to secondary anemia. As the tumor grows, pressure symptoms develop which are often indefinite at first. Bladder irritability is common. Pain is a late symptom, but pelvic discomfort and backache, particularly on exertion, is not uncommon. Some women with the complaint of sterility are found to harbor a myoma. In a great many patients, however, the myoma is first detected as a firm lower abdominal mass presenting usually just above the symphysis.

Diagnosis is made fairly easily by bimanual palpation of the pelvis. Examination should reveal not only the existence of the tumor, but also its location, extent and type. Differential diagnosis includes a normal pregnancy, cyst of the broad ligament, ovarian tumors, pelvic inflammatory disease, and malposition of the uterus. Repeated examinations at

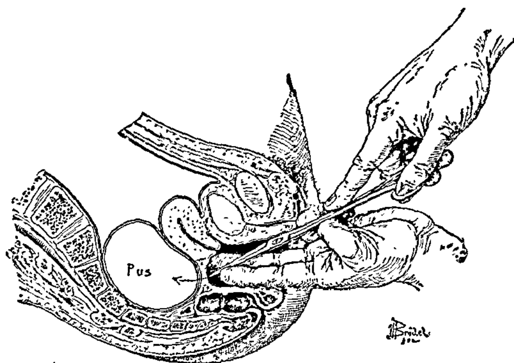


Fig. 10. Pelvic abscess; a common location in the cul-de-sac. The drawing also shows the manner by which such an abscess may be drained. (After Kelly.)

mors produce symptoms of gradual onset; there is no fever or much menstrual disturbance or history of pelvic infection. The mass is lateral and while fluctuant is not tender. 6. *Tubal pregnancy* besides its other features (see p. 1110) is associated with a positive test for pregnancy; however, this is true in only 50 per cent of cases. 7. *Other conditions,* such as chronic appendicitis and diseases of the bladder, colon, and rectum, nearly always can be excluded by the absence of tenderness and other local signs and by the manifestations characteristic of these conditions as noted elsewhere in the text.

Treatment of chronic pelvic inflammation, whatever the cause, may be either operative or nonoperative. Satisfactory relief of symptoms may be achieved by the latter, which consists of chemotherapy, psychotherapy, and other measures, such as bed rest, local applications of heat, and general hygiene, including good food, plenty of fluids, and care of fecal stasis. In some patients the presence of pus low in the pelvis, especially in the cul-de-sac, will necessitate incision and drainage through the vagina (Fig. 10).

Abdominal operation may be indicated in the presence of a tender mass obviously containing pus. Transperitoneal drainage is especially important in certain patients with puerperal infections in whom a general septicemia from absorption is feared and in whom vaginal drainage is impossible or inadequate. The danger of inducing a general peritonitis was greatly feared in the past but has all but disappeared with the use of well selected chemotherapy. On the other hand, if abdominal operation is carried out for a tubo-ovarian abscess of nonpuerperal origin, complete removal of the inflammatory mass is preferred to incision and drainage. Each patient, however, must be considered individually in making a decision as to the time for and the type of operation with special reference to the influence of chemotherapy. The indications for abdominal operation in chronic pelvic inflammation are especially difficult in the absence of clinically detectable suppuration. A few general principles may be mentioned. If the infection is due to the gonococcus, nonoperative treatment is generally advisable, especially with chemotherapy which has supplanted most of the older methods and minimized the need for operation. Operation for removal of diseased tissue is indicated only after the lapse of several

known until the brilliant observations of Sampson (9) revealed its true mechanism, at least in those implantations occurring in the ovary and pelvic peritoneum. Endometrial tissue may penetrate the wall of the uterus by direct extension (adenomyosis) or may escape through the tubes and become implanted anywhere in the pelvis or peritoneum; it may likewise spread by mechanical (operative) means, or by way of lymphatics and veins, or be displaced during embryonic life. The process of endometrial transplantation is often called endometriosis. The most frequent site of endometrioma is the ovary, but it has been found in the tubes, rectovaginal septum, rectum, sigmoid, broad ligament, round ligament, appendix, and even in the wall of the small intestine. It occurs most frequently between the age of 25 and menopause.

Clinical manifestations depend somewhat on the site of the cyst but in most cases consist of pain during and after menstruation. Atypical pain which occurs only during the menstrual period should always excite a suspicion of endometriosis, which actually is more common than is generally supposed. Other manifestations include abnormal menstruation, dyspareunia, intermenstrual abdominal pain, sterility, sacral backache, and pain in the rectum or bladder related to menstruation. Many cysts which are located on the right side are operated on with a diagnosis of acute appendicitis. Sudden rupture of the cyst into the peritoneal cavity may occur with transient collapse. Adhesions from partial rupture may produce intestinal obstruction. A correct diagnosis, however, is usually made only at operation, but even then only if the surgeon is aware of the possibility or notes the characteristic chocolate colored or bloody contents of the tumors. In some cases only on microscopic study is the true nature of the lesion revealed.

Treatment consists of excision, taking precaution to prevent further implantation. Effort should be made to preserve at least part of one ovary unless the patient is past menopause. Radium and x-ray therapy are rarely indicated.

Carcinoma of the Uterus. Uterine cancer is common formerly comprising 14 per cent of the deaths due to malignant disease. It occurs more commonly in the cervix than in the body or fundus (5:1). In the cervix it was formerly more frequent, now is less frequent than mammary cancer.

In the *cervix*, carcinoma produces ulceration and destruction of tissue, forming a fungating growth (Fig. 12) which invades by direct extension into the parametrium, and through the lymphatics into the iliac nodes, and through the blood stream to distant organs, including the lungs. There are two types, the squamous cell and the adenocarcinoma. The former arises from the vaginal portion of the cervix or the extension of the squamous epithelium just inside the external os; the latter arises from the cylindrical cells lining the glands in the cervical canal. Squamous-cell carcinoma is far more frequent (8:1).

The first and most important clinical manifestation is abnormal bleeding. The vaginal hemorrhage may be small in amount, not more than a mere "spotting," occurring between periods or it may be present as a menorrhagia. Recurrence of menstruation in women after the menopause is always suspicious and demands examination. Next in importance is leukorrhea, which may be overlooked by the patient until it becomes foul, profuse, or blood-tinged, which occurs later. As indicated above, leukorrhea is most often due to chronic cervicitis; the role of such chronic irritation in the etiology of cancer, particularly of the squamous cell type, must be considered at least in older women in whom cancer of the cervix is common. Pain and other local manifestations of malignant disease of the cervix are usually present only in the terminal stages.

Diagnosis depends upon a careful direct visualization of the cervix by means of a vaginal speculum. Lesions which are not cancer usually respond rapidly to treatment. Chronicity, persistence, and failure to heal should arouse a suspicion of cancer. However, delay in diagnosis is unjustified because an adequate biopsy is so easy and will lead to a definite diagnosis. The danger of spreading the malignant cells by biopsy is remote. Hyperplastic or deeply ulcerating lesions, particularly those which bleed easily when touched with an applicator and are associated with induration, are considered cancerous.



Fig. 11. Large globular myoma choking pelvis, compressing rectum and bladder and forcing bladder up into the abdomen. Note the retroflexion of the uterus. (After Kelly.)

reasonable intervals may furnish evidence as to the rate of growth and the development of secondary changes.

Treatment may not be necessary if the tumor is not producing symptoms. The diagnosis in these cases is usually made accidentally. However, if the tumor is in the cervix, removal is indicated for prophylactic reasons (Crossen). When the tumor is producing definite symptoms, removal by abdominal operation is the procedure of choice and is curative. Palliation for temporary relief of symptoms, or when curative procedures are refused or impossible, consists of uterine astringents (ergot, and so forth), vaginal douches which, however, are seldom effective. A thorough study has been reported by Corscaden (8), who achieved satisfactory results in over 95 per cent of a series of cases comprising 30 per cent of his patients with myoma. In general, radiotherapy may be used but only for the control of bleeding in patients at or near the menopause, when the tumor is not too large, when there is no adnexal disease. It should be emphasized, however, that in the presence of bleeding a diagnostic curettage must precede therapy in order to rule out malignancy.

Endometriosis (Endometrial Cyst). The tumor in this disease is not a neoplasm at all but a cystic swelling which forms because endometrial tissue is implanted, misplaced, or develops (by metaplasia) at various sites outside the uterus; secretions are formed at each menstrual period and may accumulate with a resultant gradual increase in size of the cyst. The bloody contents of the cyst change with time to a brownish color, giving rise to the term *chocolate cyst.* For a long time the pathogenesis of this tumor was un-

ectomy preceded and/or followed by radiotherapy with a likelihood of 70 per cent five-year survival. Excellent results have been obtained by radiotherapy alone in patients who are poor operative risks.

Chorioepithelioma (Deciduoma Malignum). A rare but exceedingly rapid-growing and fatal tumor of the uterus, it arises from the fetal cells covering the chorionic villi, and hence may occur weeks or months after normal delivery or miscarriage. It is especially likely to follow hydatidiform mole, a degenerative neoplasm related to the growth of the placenta which is well described in obstetrical texts (Williams). It produces persistent bleeding and early pain. Diagnosis is made only after curettage. Practically all chorioepitheliomas produce chorionic gonadotrophin in sufficient quantity to give a positive pregnancy test by any of the methods in routine use. Treatment is unsatisfactory where metastases are present. When the lesion is presumably confined to the uterus, hysterectomy should be done.

Sarcoma. Sarcoma of the uterus may occur spontaneously but usually forms at the site of a myoma. Rapid growth in a myoma should always suggest the development of malignant change, although sarcoma sometimes grows slowly. Diagnosis is often made only on section of the tumor. Treatment is surgical excision.

THE OVARIES

The ovaries are the site of a great variety of tumors, 95 per cent of which are cystic. A complete but brief classification is that reported by Gardner and Trout. Besides the true neoplasms (both epithelial and mesodermal) which include benign and malignant groups, retention cysts occur commonly, and teratomas uncommonly, in the ovary. Inflammatory cysts (abscesses) have already been considered under chronic pelvic inflammatory disease. The pathology and clinical course vary in each type of cyst; but there are two complications which may occur in many of them: rupture of the cyst and rotation (torsion or twisting) of the pedicle.

Simple Retention Cysts. These nonproliferating cysts comprise a variety of types. Among them are Graafian follicle cyst (due to failure of the follicle to rupture), corpus luteum cyst (due to failure of normal luteal absorption), and tubo-ovarian cyst (union of ovarian cyst and tube, usually of inflammatory origin). These cysts are small, rarely larger than an egg, and produce no special symptoms, except, on occasion, abnormal bleeding. They are noted during celiotomy most commonly, and are frequently resected, leaving as much normal tissue as possible.

Cystadenoma (Ovarian Cyst, Proliferating Cyst). Cystadenoma represents a benign epithelial neoplasm which is the most common of the true ovarian tumors. There are several types. The small unilocular type is called simple serous cystoma, which is rarely larger than an infant's head. The larger multilocular type is called pseudomucinous cystadenoma and represents the classical ovarian tumor whose removal really established gynecology as a specialty and paved the way for other abdominal operations. Many cysts contain proliferating epithelial masses, and represent a special group which are called papillary tumors or papillomata. Some are pedunculated; a few are located in the broad ligament. Paraovarian cysts originate in the tubular remains of the embryonic Wolffian body and account for 10 per cent of excised cystic tumors of the ovary. Most cysts of the broad ligament are paraovarian in origin. The pathology of the various tumors is fairly complex and a great many variations have been described. Many grow to a large size if untreated, because of the accumulation of serous or pseudomucinous fluid within the cystic areas. They occur at any age but are most common between the twentieth and fiftieth year. The small serous cysts are usually bilateral.

Clinical manifestations consist of mild symptoms of pelvic discomfort which brings the patient to the doctor for examination. The small serous cyst may remain stationary and silent; the proliferating cysts grow slowly, usually taking several years to reach an appreciable size, but never cease growing. In the late stages the large amount of fluid contained in the cyst may be mistaken for ascites (Fig. 13). The growth of the tumor may simulate a normal pregnancy since menstrual disturbances are not infrequent. Bimanual pelvic examination usually suffices to make the diagnosis. The pedunculated cysts, how-



Fig. 12. Squamous cell carcinoma of the cervix. Photograph of the view obtained by retracing the vaginal walls. The cervix is entirely replaced by malignant disease. The patient, aged 32, had had leukorrhea for some time but only for a few months had it become, first brownish, and later red, in color. Biopsy confirmed the clinical diagnosis. Radiotherapy was instituted with satisfactory conversion of the diseased tissue to extensive scar. Complete destruction of the tumor, however, was probably not achieved. (St. Louis City Hospital.)

Examination of the vaginal smear for malignant cells is becoming popular because of its simplicity and promises to yield earlier diagnoses. However, suspicious smears must be confirmed by a biopsy before a positive diagnosis is made.

Radical excision (panhysterectomy) was formerly the recommended procedure but was abandoned because of the high mortality *and because radiotherapy proved so effective.* Extensive resection was reintroduced because it is now followed by a low operative mortality. Recent study indicates that properly used radiotherapy still achieves as good results. The percentage of five-year cures varies between 70 per cent in the very early cases to 50 per cent in the slightly advanced cases. Radical surgery (pelvic evisceration) is now reserved for the few patients who do not respond to, or recur after, radiotherapy. Since cervical cancer tends to remain localized, such a sequence is justified.

In the *body of the uterus,* adenocarcinoma is fairly common. At or before the menopause cervical carcinoma is more frequent, but after the cessation of menstruation the incidence is about equally divided. Any vaginal bleeding after the menopause is always suggestive of malignant disease of the uterus. Diagnosis, *however, depends on microscopic* examination of tissue obtained by curettage. In the presence of a normal cervix (myoma and periuterine disease being excluded by palpation), chronic endometritis may produce bleeding and discharge which may be mistaken for carcinoma. This lesion, however, responds rapidly to conservative treatment in most cases. If bleeding persists, curettage should be performed for the purpose of diagnosis. Treatment consists of complete hyster-

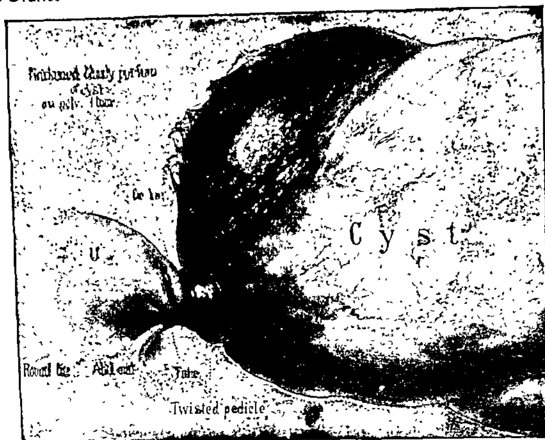


Fig. 14. Acute torsion of an ovarian cyst. The pedicle includes also the uterine tube, ovarian and round ligaments. (After Kelly.)

sected, all of the remaining normal ovary should be left, particularly in younger individuals.

Dermoid Cysts. Dermoid cysts may produce symptoms similar to those already mentioned but are quite different pathologically. They occur at any age and are in reality *teratomas* in which the skin elements predominate. They are more likely to become infected than other cysts and being more adherent are often more difficult to excise. They seldom undergo malignant change. Treatment consists of excision of the tumor, preserving ovarian tissue if possible.

Solid Tumors. Solid tumors of the ovary are somewhat rare, comprising but 5 per cent of all neoplastic diseases of the ovary which come to operation (Crossen). The benign growths are the *fibroma* and *myoma*, which are usually small and are diagnosed only at operation or by microscopic section. *Granulosa cell tumors*, because of their endocrine effects, are discussed in Chapter 39.

Carcinoma of the ovaries may rarely develop as a primary solid tumor, usually of the medullary type. Most frequent is the carcinoma which forms in a cystadenoma possessing papillary ingrowths. This type is called malignant papillary cyst and presents the same clinical manifestations as a cystic tumor of the ovary. The true diagnosis is often made only on microscopic study of the excised cyst. A third group comprises tumors which occur in both ovaries, but which are secondary to cancer elsewhere in the peritoneal cavity, most commonly the stomach or colon. When they assume a scirrhous form, they are associated with the name of Krukenberg. Sarcoma has also been observed in the ovary and is important in children, in that it comprises nearly one half of ovarian neoplasms in early life.

Early diagnosis in malignant disease of the ovaries is nearly always difficult, if not impossible, on clinical grounds alone, unless operation is performed, at which time the

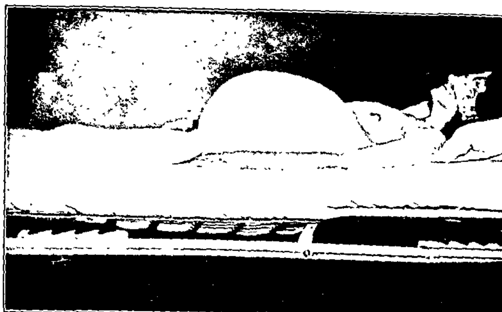


Fig. 13. Ovarian cyst. Note the characteristic manner in which the swelling rises sharply symphysis; this is not true of abdominal distention and ascites. The patient, a 48-year-old eight months previously, noted a small tumor just above the pubis; it grew steadily to its pr Edema of the feet and ankles developed more recently. At operation a large cystadenoma of th cular pseudomucinous type was removed as well as a myomatous uterus and the opposite ad covery was uneventful. (Gynecological Service, Barnes Hospital.)

ever, are so freely movable that their origin from the pelvis may be difficult to demonstrate except at operation. On rare occasions gradual rupture of a cyst may result in adhesions to neighboring structures. An acute abdominal emergency may be precipitated by sudden rupture; more commonly such a picture is due to *torsion of the pedicle,* which is more common in the smaller cysts, including the retention and simple serous cysts. Severe lower abdominal pain, nausea, vomiting, and leukocytosis follow provided the twist is sufficient to interfere with the blood supply. If gangrene occurs, the patient may become prostrated and go into shock. In a few instances the twisted pedicle involves the gut, producing the manifestations of acute intestinal obstruction. The palpation of the mass may be sufficient to make the diagnosis.

Differential diagnosis in the small ovarian cysts includes consideration of tubal swellings which are due to inflammatory disease (salpingitis, pyo- and hydro-salpinx), tubal pregnancy, myoma, retroverted pregnant uterus, and broad ligament cyst. In the larger cysts, such conditions as abdominal distention (paralytic ileus), obesity, ascites, pregnancy, degenerated cystic myoma, and ab tumors (hydronephrosis, hydrops of bladder, and so forth) are to be cor Ascites, however, is often associat malignant ovarian tumors which scribed on page 1109. In a few c nature of the tumor will not be rec until laparotomy.

When acute torsion of the pedicl ovarian cyst occurs (Fig. 14), the dif diagnosis demands consideration of a pendicitis, rupture of ovarian cyst or p renal or gallstone colic, acute intesti struction with strangulation, ruptured pregnancy, mesenteric thrombosis, deed all of the other acute abdominal already discussed elsewhere (see Ch. 3

Treatment of ovarian cyst is urgen torsion of the pedicle or acute rupture and it consists of immediate celiotom excision of the tumor. Under ordina cumstances removal of the smaller c cysts is indicated in order to prevent growth or torsion and because of the of malignant regeneration. The small bi cysts which produce little or no sym rarely justify operation, but if they a

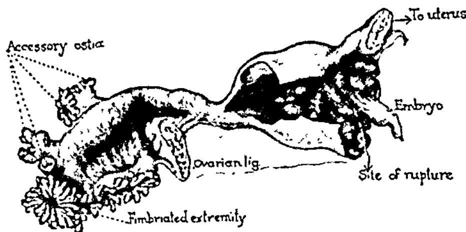


Fig. 15. Ectopic (tubal) pregnancy; specimen removed at operation. Inside the ruptured blood clot, the tiny embryo could be made out on careful gross inspection. The patient, aged 15, was suddenly seized with acute abdominal pain in the right lower quadrant, 30 hours before admission. The pain remained severe and was referred to the upper abdomen and under the shoulder blades; prostration, shock and pallor developed rapidly. The erythrocyte count was 1,500,000. At operation the peritoneal cavity contained a great deal of clotted blood.

infrequently, rupture into the peritoneal cavity produces a sudden intraabdominal hemorrhage with collapse and manifestations of surgical shock. If the patient recovers, or the bleeding is slow, a marked secondary anemia develops. It is rare for ectopic pregnancy to proceed to term without rupture, but when this occurs, it is usually an abdominal pregnancy.

Clinical Manifestations. Before rupture occurs, the patient may be asymptomatic, or note only the signs and symptoms of early pregnancy, i.e., amenorrhea, slight pelvic pain, increasing nausea, pain in the breasts, or general malaise. In some patients there will be a history of previous pelvic inflammatory disease. Bimanual examination will often be diagnostic, not only in detecting a mass, but also in revealing a soft, succulent cervix and a uterus which is slightly enlarged. However, because of the paucity of symptoms, it is rare for a patient to consult a physician with an unruptured tubal pregnancy. In most instances acute rupture of the growing ovum produces sudden and severe manifestations which are the first indication of disease; the diagnostic accuracy of a pregnancy test is unfortunately of little practical value in such cases because it requires too much time to carry out when an immediate diagnosis is necessary.

Acute rupture often follows exertion, but may be spontaneous. The clinical manifestations in the severe cases are of dramatic suddenness, the patient falling to the ground in profound collapse. Unlike the collapse following rupture of a peptic ulcer, there is evidence of circulatory shock of the type due to severe hemorrhage. The pulse is rapid and weak, the blood pressure low, the extremities are cold and moist, the skin extremely pale, and air hunger is present. Nausea and vomiting are frequent because of the peritoneal stimulation by the blood. The abdomen is tender to palpation and may be distended with fluid. Pain is, of course, severe, but usually unilateral. Pelvic examination reveals the presence of a bulging, boggy mass in the cul-de-sac; an adnexal tumor may also be palpable. A bloody vaginal discharge is often present. Aspiration of pure blood from the cul-de-sac is often of considerable diagnostic aid.

The patient may recover rapidly from the initial collapse because of cessation of bleeding and efficient encapsulation of the blood clot. In many patients recovery is slow and accompanied by signs of marked secondary anemia. Occasionally there may be no acute manifestations of rupture, the patient gradually becoming weaker and more anemic. The pregnancy test is of especial value in this type of patient, provided that the fetus is still viable.

true nature of the tumor can often be ascertained by gross inspection. Frequently, however, the existence of malignant disease becomes evident only after study of the microscopic sections, especially in the case of cystic tumors which have become malignant. In the late cases the presence of severe pain, extensive masses, or ascites is frequently noted. Treatment consists of excision; radiotherapy is also used, especially in the form of colloidal gold left in the peritoneal cavity in extensive disease.

THE FALLOPIAN TUBES

Tumors in this location are exceedingly rare and are usually mistaken for the various neoplasms which originate in the ovaries, uterus, or broad ligaments. The small cysts or hydatids of Morgagni are seen at the fimbriated end of the tube but have no clinical significance.

THE VAGINA

Solid tumors are so rare as to require no special consideration. Malignant disease is usually secondary to that of the cervix, although primary carcinoma occurs, usually on the posterior wall. Squamous cell carcinoma is seen in the vulva (see p. 1115). Cystic tumors are not so rare and comprise epithelial inclusion (epidermoid) cysts which form in the scar following lacerations or perineal operations; cysts arising in the glands of the vaginal wall which are rare; congenital cysts due to embryonic inclusions, which are likewise uncommon. Bartholin's gland cyst at the vaginal outlet is not infrequent and is described under diseases of the vulva.

MISCELLANEOUS CONDITIONS

Normal Pregnancy. Normal pregnancy not infrequently simulates acute abdominal disease. In some instances the patient may not herself be aware of the true diagnosis; in a few women, such knowledge is withheld in the hope that an operation may be performed which will result in abortion. Abdominal pain, vomiting, local tenderness, muscle spasm, and leukocytosis may lead to a diagnosis of acute appendicitis. Even if the history is unreliable, bimanual examination will rarely fail to establish the true state of affairs.

If the diagnosis is not urgent, any doubt may be dispelled by the Aschheim-Zondek test which consists of the injection of the patient's urine (or blood) into a young immature female rat, which is killed 18 to 48 hours afterwards. If the patient is pregnant, characteristic changes will be seen in the ovaries. In the Friedman test, a modified Aschheim-Zondek procedure, a rabbit is utilized. The male frog test is also useful (Haskins, 10). The test is positive even in the early weeks of pregnancy. A negative test (especially when repeated) rules out pregnancy in 85 per cent of cases.

The coexistence of a normal pregnancy with other surgical disease may present problems particularly in the case of suspected intraabdominal disease. In general, the pregnancy is no contraindication to needed operation provided adequate care is taken to minimize a miscarriage. In the case of carcinoma of the breast, other considerations apply.

Ectopic (Extra-Uterine) Pregnancy. When a fertilized ovum lodges and grows outside the uterine cavity, the patient suffers from an ectopic pregnancy (Fig. 15) which obviously cannot result in a normal delivery. In nearly every instance serious symptoms develop within a few weeks or months after conception because of local bleeding which arises from erosion of the vessels by the trophoblast or from rupture of the tube due to distention. The hemorrhage may be either sudden and profuse, slow and persistent, or encapsulated. The ovum is most commonly lodged in the Fallopian tube (tubal pregnancy) but may develop in the peritoneal cavity (abdominal pregnancy) or in the broad ligament. The etiology of ectopic pregnancy is nearly always a mechanical interference with the passage of the fertilized ovum through the tube into the uterus. Inflammatory adhesions are often thought to be the most common cause, though careful work has shown that various malformations (diverticula) play the most important role. The pathology varies with the location of the fetus as well as its viability. When the mass ruptures but remains encapsulated in the tube, the sudden symptoms will subside, and a local mass will form (tubal abortion). A localized hematoma in the broad ligament or cul-de-sac or a tubo-ovarian hematoma may form in a similar manner. Not

"motor of the ovary." A delicate balance exists between the hormones of the ovary and pituitary which is described below. Other endocrine glands, such as the thyroid and adrenal, also exert important, though lesser, influences on the ovary and pituitary. Indeed, there is growing evidence that a balance exists between many if not all endocrine glands —an interesting general phenomenon which is made still more complicated by the influences exerted on them by the autonomic nervous system.

The cyclic production of ovarian hormones, controlled in turn by the pituitary, is responsible for the periodic changes in the uterus and breast. The mechanism is somewhat complicated but fairly well understood. Before explaining this mechanism, it may be useful to enumerate a few of the hormones, many of which have been isolated in crystalline form and, indeed, synthesized. The pituitary hormones affecting the ovary are a follicle-stimulating hormone (FSH), a luteinizing hormone (LH), and luteotropin (probably the same as lactogenic hormone), which maintains the functional state of the corpus luteum. The ovaries produce two hormones, one group called estrogens, which originate from the Graafian follicles and the corpus luteum, the other progesterone, which originates in the corpus luteum alone. Progesterone (formerly called progestin) was first isolated in pure crystalline form in 1934 by Wintersteiner and Allen (11). The important part of the mechanism of these two groups of hormones, as far as their cyclic behavior is concerned, is the reciprocal relationship they bear to each other by which the pituitary stimulates the ovary to produce hormones which in turn inhibit the pituitary, thus setting at rest (for a while) the stimulus to ovarian activity. The consequent fall in the production of ovarian hormones then removes the inhibition from the pituitary, which begins to act again; the ovary is then stimulated, completing the cycle.

The cyclic changes in the uterus and breast are, therefore, due to the periodic increase and decrease of the ovarian hormones, governed in turn by the reciprocal stimulation and suppression of pituitary activity. Of the changes in the uterus, vascularization and hyperplasia are stimulated by the estrogens whereas secretion of the uterine glands is due to the presence of progesterone. These changes cease with the fall in the hormone concentration, which also corresponds with the appearance of the menstrual flow; the onset of menstruation has been shown to coincide with the diminution of the ovarian hormones. The ebb and flow of the ovarian and pituitary hormones thus accounts for the regular cycles which occur in normal females. It is obvious that with this cycle, the hyperplastic changes in the uterus and breast are succeeded by involution or regression back to the resting stage. In the breast, absence of this regression or hypoplasia may result in a nodular condition of the parenchyma, usually called chronic cystic mastitis (see Ch. 35). When pregnancy occurs, the cycle is temporarily upset and under these conditions the large amounts of gonadotropic hormone are produced by the placenta. This hormone is called human chorionic gonadotrophin (HCG). This secretion begins soon after conception and makes possible the early detection of pregnancy by injecting blood or urine into laboratory animals. Many such tests for pregnancy are in general use. Some tests utilize the effect of chorionic gonadotrophin on the ovaries of rodents (Aschheim-Zondek), others the effects in the ovaries of rabbits (Friedman), and still others the capacity of this hormone to induce ovulation or to release sperm in amphibians (*Xenopus laevis* test; male frog test). As pregnancy proceeds, the amount of chorionic gonadotrophin rapidly increases, reaching a maximum at about two months of pregnancy. The amount then decreases but remains sufficiently great to give a positive test throughout pregnancy.

The difficulties in applying this knowledge to gynecologic disturbances are due not only to the number of hormones involved, but particularly to their balanced relationship. Thus we may consider not only the effects of overactivity and underactivity of the ovaries, but also an imbalance between the pituitary and ovaries. These factors make diagnosis more difficult. Therapy is complicated, too, by the delicacy of the threshold for these hormones; a certain dose will produce one effect whereas a larger dose quite a different one, dependent partly upon the stage of the cycle in which they are given, but also on other factors, such

Differential diagnosis in acute rupture rests between the following five diseases. 1. Perforated peptic ulcer, which is extremely rare in women and is not accompanied by circulatory shock. 2. Abortion has a similar history, but the pain which consists of intermittent cramps is localized to the region of the uterus and gradually increases in intensity. Vaginal bleeding may be present in either abortion or ectopic pregnancy, but is much more profuse in the former condition. Pelvic examination is obviously important. 3. Acute exacerbation of chronic salpingitis is accompanied by little or no prostration and no circulatory collapse; the pain is usually bilateral. 4. Acute appendicitis is accompanied by no pelvic signs and produces characteristic gastrointestinal symptoms and signs. 5. Torsion of an ovarian cyst is apt to be confusing, but the history is different; there is no anemia, and pelvic examination reveals a normal cervix and uterus, as well as the location of the mass, which is higher in the pelvis than is an ectopic pregnancy.

TREATMENT. Patients with an unruptured tubal pregnancy should be subjected to celiotomy and the mass excised. In this way the almost certain danger of rupture is avoided. When rupture has resulted in an encapsulated hematoma, further bleeding may stop provided the embryo has ceased growing. Even so, operation is usually necessary in order to remove the placenta and other tissue so as to prevent hemorrhage later. In the acute cases operation is an urgent emergency in order to prevent death from shock. Treatment of the shock is carried out at once and is continued during and after the operation; the intraperitoneal blood may be used as soon as it is obtained (autotransfusion), provided, of course, it is not clotted. The most difficult cases technically are those in which the placenta is attached to the peritoneum rather than to the tube. However, it is advisable and usually possible to conserve the ovary on the affected side.

ENDOCRINE DISTURBANCES

The most important advance in gynecology in recent years has been the investigations of the hormones which govern the activities of the genital organs. These studies, which were to a large extent initiated by Born, Fraenkel and Leo Loeb, and recently developed by Edgar Allen, Willard Allen, Doisy, Corner, Evans and others, have explained much regarding the mechanism of menstruation and the changes following conception and pregnancy. Moreover, it is now recognized that many conditions, previously ill understood or attributed to organic disease and uterine malposition, are in reality due to endocrine disturbances. Many of these patients with endocrine deficiencies can be satisfactorily treated by administering the hormone which is absent. Diagnosis is obviously important but extremely difficult in most instances. Direct analysis of blood or urine to determine the amount of hormones is possible but laborious. There is no test as simple as the basal metabolism test which determines the presence of hypofunction and hyperfunction of the thyroid. Great strides in the identification of conditions caused by ovarian dysfunction will no doubt be made within the next few years. The clinical evidences of abnormal endocrine function are only partly useful. The menstrual flow itself is only one manifestation of ovarian hormone activity. Changes in the endometrium are useful but are detectable only by curettage. In the mammary gland, endocrine effects can be determined only to a slight extent by palpation; accurately, only by biopsy. Thus, much of the status of our knowledge of endocrine disturbances is incomplete and complicated, because of intrinsic difficulties in measuring their clinical manifestations. A few general principles, however, have been established, and these will be briefly described. Further details may be found in publications by others (6). The chapter on endocrines in this volume should also be consulted.

As the female gonad, the ovary has two functions, the maturation of the germ or ovum (ovulation) and the production of hormones. The latter function is responsible for the development of secondary sex characteristics and governs the periodic changes in the uterus (menstruation), in the mammary glands and other organs. This periodicity (roughly 28 days) is one of the important features of ovarian activity. The stimulus to the ovary is the presence of gonadotropic hormones produced periodically by the pituitary which is thus often referred to as the

ciently large amounts, and this is now possible by giving them in relatively pure form. In treating menopausal symptoms the estrogens are most useful and are widely employed. Stilbesterol, a new compound, synthesized by Dodds and his co-workers, has also been found to exert therapeutic estrogenic effects.

Functional Uterine Bleeding. Abnormal bleeding from the endometrium, due to disturbances in ovarian function, occurs frequently during adolescence and the climacteric. The bleeding may be prolonged and profuse. The endometrium usually shows no progestational change. In most instances the ovaries contain numerous Graafian follicles but no corpora lutea, indicating that the abnormal bleeding is associated with a failure of regular periodic ovulation and corpus luteum formation. The bleeding, which is almost invariably painless, especially in young individuals, can be interrupted and the cycle restored to normal by the use of progesterone. On rare occasions, excessive production of estrin may be due to *granulosa cell tumors* of the ovary which is discussed on page 1084.

DISEASES OF THE VULVA AND VAGINA

The vagina and vulva are the site of disease which should offer no diagnostic difficulty, chiefly because the lesions are external and are easily examined by direct inspection. Many have already been considered in detail.

Vulvovaginitis. Primary inflammation is rare, secondary lesions frequent. Redness of the external genitalia, edema, pain, and heat are similar to the cardinal signs of acute inflammation anywhere in the body, although the signs are more superficial, rarely involving the deeper structures. Pain and burning, when present, are usually aggravated by walking. Such manifestations may indicate the onset of a *gonorrheal infection* as already described. The inflammation is due to invasion by the gonococcus only in the primary stages of the disease; in the later stages the irritant vaginal discharge which originates in most instances not from the vagina but from the cervix is responsible. Indeed, any irritating vaginal discharge, whether of gonorrheal origin or not, leads to vulvitis. In some cases, irritating urine is apt to be an important cause. Vulvitis may also be secondary to other factors, such as pediculosis, masturbation, chafing, or uncleanliness. Skin lesions of various sorts may be present in the external genitalia and set up an acute inflammatory reaction; some are secondary to the acute exanthemata. Treatment consists of local care, but particularly removal of the cause.

Simple vaginitis describes a primary inflammation of the vaginal mucosa and is actually a rather rare disease. Inspection reveals the reddened, inflamed vaginal wall; the etiology may be apparent, such as an injury, a foreign body, or irritating douches. When a flagellated protozoa (*Trichomonas vaginalis*) has been found in the discharge, the term *trichomonas vaginitis* is used. The etiologic role of this organism has not been scientifically established; while many observers attribute to it a primary etiologic importance, others claim that it is a secondary invader. The vaginal discharge in these cases is particularly profuse and is thin and watery in character. Various forms of local therapy (cleanliness, vaginal douches, antiseptics) are advocated; chemotherapy is effective, although persistence and a long period of time are necessary before the organism can be permanently eradicated. As in every disease, the exciting factor in the production of the lesion should be searched for and eradicated when possible.

In older women the vagina becomes atrophic. Occasionally the walls adhere to each other; the term adhesive vaginitis is applied to this condition.

Injuries. Trauma due to childbirth has already been described. In the vulva, lacerations are nearly always located in the perineal body or located in the posterior part of the vaginal outlet. Other injuries are encountered following rape or from penetrating or lacerating wounds which children sustain in climbing trees and fences. They present the same problems of treatment as wounds sustained in other parts of the body.

Ulcers. Ulcers are found in and about the vulva just as they are elsewhere and present a similar and often a complicated diagnostic problem, except that significant circulatory factors are generally absent. *Simple ulcers* are usually due to trauma or pyogenic infection, and heal rapidly on removal of any irri-

as their effect on the activity of other organs. By analyzing the urine and blood for the content of ovarian and pituitary hormones over a long period of time, Frank and his coworkers have produced evidence of overfunctions and underfunction of the ovaries which seems of definite value in correlation with the clinical symptoms present.

Ovarian Underfunction. Ovarian function may be reduced by x-ray or radium therapy to the pelvis or by diseases such as chronic infections or undernutrition. It may likewise be due to congenital underdevelopment. Ovarian activity is abolished, of course, after surgical extirpation (artificial menopause) and normally tapers off during the normal menopause. Underfunction may be due to primary pituitary disease. The important clinical manifestations of ovarian underfunction are sterility (including certain types of miscarriage), amenorrhea (including oligomenorrhea), dysmenorrhea, and the menopause.

STERILITY. Underfunction of the ovulating mechanism may be responsible for sterility in that mature ova are not produced; if produced, they may not be discharged because of failure of the Graafian follicle to rupture. These patients may present no other clinical evidence of underfunction and menstruation may be normal. Hypofunction of the thyroid may be the cause of insufficient pituitary stimulation; the latter, however, is difficult if not impossible to determine.

In 50 per cent of sterile matings, defects in the male are responsible. Thus all factors must be considered and evaluated by thorough study, before diagnosis and treatment are possible. In many cases, sterility is less a complaint than miscarriage which may be due to progesterone deficiency readily corrected by daily administration of the hormone. Since the placenta produces considerable quantities of progesterone after the third month, such therapy is not necessary after this time.

DYSMENORRHEA. Irregular, especially painful menstruation may be produced by any of several causes. Stenosis of the cervix and malposition of the uterus are important factors. In other instances it may be due to ovarian underfunction; if this is definitely determined, treatment with the missing hormone, ovarian, or pituitary, is indicated. Dysmenorrhea, however, may be present with excessive menstruation which is usually considered to be due to abnormal function of the ovaries (see below). In a number of patients with dysmenorrhea the etiologic factor has been allergic; relief has followed elimination of substances to which the patient is sensitive.

AMENORRHEA. Failure of menstruation is a symptom which, in itself, should produce no disability. It occurs normally during pregnancy and in many nonpregnant women, without interfering with general health. Similarly, oligomenorrhea or scanty menstruation may be present without clinical significance unless the patient is concerned about it psychologically; in sterility, of course, it assumes considerable importance. Amenorrhea may be due to ovarian insufficiency of ovarian origin (maldevelopment), debilitating systemic disease, or to the absence of pituitary hormone; however, other causes, inflammatory, neoplastic, and operative (hysterectomy), must obviously be excluded before a diagnosis of endocrinopathy can be considered. Treatment depends upon the cause, detection of which should be established, if possible, by thorough study. Clinical manifestations of ovarian activity, occurring in spite of complete amenorrhea, are grouped together and called *molimina;* they consist of engorgement of the breasts, pelvic heaviness, and periodic leukorrhea. Evidence of the cyclic production of ovarian hormones has been found in these patients.

Amenorrhea at the menopause may lead to disturbing symptoms, especially when an artificial menopause has been tragically and often needlessly produced in young women by gynecologic *furor operativus*. These clinical manifestations consist of a variety of neurovascular, psychic, and other disturbances which are frequently severe enough to demand therapy. True substitution organotherapy was attempted decades ago by H. A. Kelly, who gave such unfortunate young women sandwiches spread with minced hog ovaries obtained from an abbatoir close to the Johns Hopkins Hospital. It is now known, of course, that such attempts at replacement therapy were entirely useless because the dose was completely inadequate. To be effective, ovarian hormones must be given in suffi-

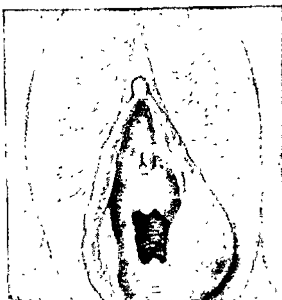


Fig. 17. Bartholin's gland abscess. Note the characteristic location. The patient, a 23-year-old housemaid, contracted gonorrhea several weeks previously, but suffered very little disability until severe pain, aggravated by walking, developed with the appearance of a tender mass in her vulva several days before. Incision and drainage resulted in immediate relief; the causative organisms were found in the pus

of the vulva is thus advisable in all cases of leukoplakia or kraurosis in order to eradicate the lesion before it undergoes malignant change (Taussig). Treatment of the lesion when definitely carcinomatous should include excision of the regional lymph nodes, as well as radiotherapy.

Cysts are nearly always confined to Bartholin's glands which are located on either side, just inside the posterior portion of the labia (Fig. 17). Bartholin's glands normally produce a mucoid secretion which lubricates the inner labial surfaces; they are not infrequently the site of infection, forming abscesses which produce the usual acute manifestations and often require incision or open spontaneously. These abscesses are nearly always associated with acute gonorrheal infections. If the opening of one of Bartholin's glands becomes occluded because of inflammation, or if an acute abscess subsides without drainage, a Bartholin cyst may develop. Such a tumor is rarely of large size but may cause sufficient discomfort to demand excision.

A soft swelling which is present in the labia may really be due to a *pudendal hernia* or to a hydrocele of the canal of Nuck. These lesions have been described elsewhere (see Ch. 34). Swellings due to varicose veins are also seen, particularly during pregnancy.

Pruritus Vulvae. The severity varies greatly, but may become a serious cause of disability. Detection of the cause is obviously important, and a thorough history and physical examination is a *sine qua non*. Pruritus is not a disease, but only a manifestation of a disease, the nature of which may require much study before it is detected. In many patients, the cause will be found in the presence of irritating vaginal discharge or of irritating urine, *especially in diabetics*. *Skin diseases* of various types, such as eczema, leukoplakia, or kraurosis may be present. Lack of cleanliness, foreign bodies, fungus infection, and many other factors are sometimes of importance. Psychogenic factors may be prominent. Treatment consists of the eradication of the cause and the application of soothing lotions and cleanliness; fungicides may be indicated in some cases.

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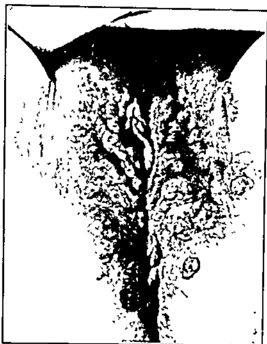


Fig. 16. Condyloma latum. Secondary luetic lesions of five weeks' duration, around the vulva, in a 35-year-old housewife followed a definite history of exposure; severe itching was the only complaint. The Wassermann reaction was positive. The lesions disappeared within a few days after intensive antiluetic therapy. (St. Louis City Hospital.)

tating factors. Frequently, simple ulcers are produced at the vaginal outlet because of excessive and irritating vaginal discharge. Ulcerations due to *chancroidal* infection, have been described elsewhere (Ch. 7). Ulcers due to syphilis may be primary or secondary, i.e., the *chancre* and *flat condyloma*. In both, the causative organism may be demonstrated in dark field illumination of the discharge from the lesion. The chancre has a hard indurated base and is single. The flat condyloma (condyloma latum, Fig. 16) represents multiple rounded elevations with a flat plateau surface, grayish and moist. When in the vagina, it is called a mucous patch, similar to the lesion of the mouth in secondary syphilis. The Wassermann and Kahn reaction is positive at this stage. It is easily distinguished from the condyloma acuminatum, which is described below. It should be emphasized, however, that most of the perineal lesions which are called condylomas (except the flat, syphilitic type described above, and the venereal warts described below) are in reality due to *lymphogranuloma venereum*, which has been described in Chapter 7.

Chronic hypertrophic ulcerative vulvitis is a type of chronic ulceration which is associated with an overgrowth of skin and subcutaneous tissue. It is probably due to chronic lymphangitis and is therefore a type of *elephantiasis*, a term, however, which is used only when the overgrowth of tissue becomes tremendous. Treatment depends on the symptoms produced by its size; surgical excision may be indicated. *Granuloma inguinale* also occurs about the vulva and is considered in Chapter 7.

Condyloma acuminatum (venereal wart) is a papillary and hence conical (rather than flat) skin lesion which is single or multiple, and consists of an overgrowth of the epithelial layer of the skin; unlike the true wart or verruca vulgaris, it does not penetrate the layers of the skin, but extends out from its surface. It is usually associated with lack of cleanliness and the presence of an irritating leukorrhea, especially that due to gonorrhea. Superficial ulcers may form which cause some discomfort; otherwise the warty overgrowths produce no symptoms. Local cleanliness and care of the discharge is all that is needed in the way of treatment in many cases. Others, however, are more resistant and require local excision, electrocoagulation, or chemical cauterization.

Kraurosis is a term frequently used to describe a lesion in the vulva which in reality should be called *leukoplakic vulvitis*, which has a definite histology and clinical appearance (Taussig). As mentioned below it is to be considered as a definite precursor of carcinoma. Hyperplasia of the outer skin layers is supplanted later by atrophy. Most of these patients suffer from pruritus; dyspareunia also occurs. Treatment consists of excision of the diseased skin (vulvectomy) in order to prevent the development of carcinoma.

Neoplasms and Cysts. Most benign tumors, such as fibroma, lipoma, and hemangioma, have been found in the vulva and even in the vagina. Malignant disease is confined to squamous cell carcinoma.

Carcinoma of the vulva is an important though rare type of squamous cell tumor and occurs usually only in older women; occasionally it is of the adenocarcinoma type. It is so often preceded by leukoplakia, that early diagnosis should be relatively easy. Excision

thra whereas the second glass contains only bladder urine (plus any excessive amount of urethral pus); a comparison of the two glasses often enables a differentiation between urethritis and cystitis and the degree of each. If urinalysis is necessary in an acute emergency and the patient cannot void, catheterization may be justified. In the female, catheterization is always indicated for microscopic examination, especially in the adult; otherwise a voided specimen may be used for routine urinalysis.

Unless urine is examined when fresh, inaccurate and often misleading results may be obtained, particularly in the search for bacteria, because many types of organisms may multiply sufficiently in an hour or two to give the erroneous impression of a massive bacteriuria. The routine urinalysis includes the staining of sediment with methylene blue for bacteria, determination of pH (i.e., acid or alkaline), search for pus cells, albumin, and the like.

3. Rectal examination. The tone of the sphincter is estimated in male or female. In the male, the size and shape of the prostrate and seminal vesicles are noted and prostatic fluid is expressed and examined at this time. If the rectal examination precedes the routine urinalysis, microscopic blood may be found in the urine and prove confusing.

4. Measurement of residual urine. In certain cases it is necessary to know how much urine is left in the bladder after voiding. This is known as "residual" and is drawn off by catheterization which, however, must be done within a minute or two of voiding, particularly if the patient has recently drunk considerable fluids.

5. Cystoscopic examination. The introduction of cystoscopic (retrograde) pyelography, consisting of the passage of small catheters through the cystoscope (Fig. 1) into the ureter and kidney followed by the injection of radiopaque solutions (Voelcker and Lichtenberg, 1), and an x-ray film (Fig. 2), has



Fig. 2

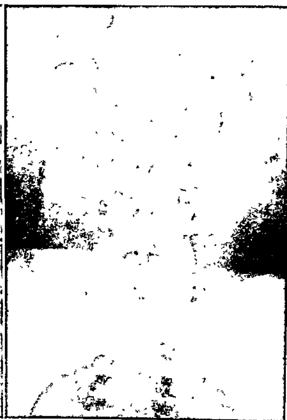


Fig. 3

Fig. 2. Normal retrograde pyelogram after injection of Urokon through a ureteral catheter.

Fig. 3. Normal intravenous pyelogram.

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THE GENITOURINARY SYSTEM

Kidney
Bladder
Prostate
Seminal Vesicles
Urethra
Epididymis
Testicle
Penis
Miscellaneous Lesions

The early use of operative procedures (cystostomy for stone) and mechanical instruments (crude sounds and catheters for urinary obstruction) in ancient times represented greater accomplishment in the treatment of surgical diseases of the genitourinary organs than of any other organ. However, the physician's ignorance of physiologic principles and the poor results obtained allowed even the sound principles to be discarded. Without special instruments, the inaccessibility of the urinary organs naturally made progress slow. However, the invention of the cystoscope (Fig. 1) by Nitze (1899), and the perfection of the technic of ureteral catheterization by Albarran (1897), as introduced a few years previously by numerous independent workers, were the means of instigating rapid development in the knowledge o diseases of the urinary system and their t ment.

Methods of Examination. Because of cessibility of the organs of the genitourin system and their simplicity of function, merous procedures for examination ha been devised. These methods of examinati have been largely responsible for the exac ness of diagnosis which exists in genitourina surgery to a greater degree, perhaps, than i most other specialties. A definite routine however, should be adopted and carried ou methodically in steps as follows:

1. History and physical examination.
2. Urinalysis. In the male the "two glass" test is made. The first glass contains enough urine to wash accumulated pus from the ure-

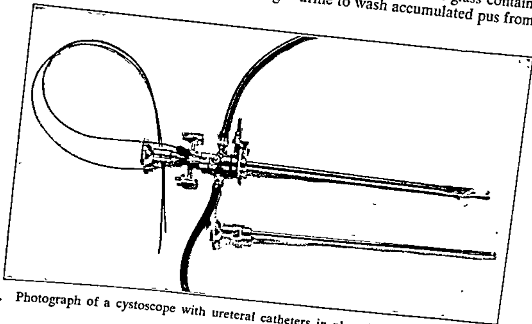


Fig. 1. Photograph of a cystoscope with ureteral catheters in place in the instrument.



Fig. 5. Aortography revealing kidney cyst on right (C—cyst).

outline of the kidney and adrenals. A needle is inserted just anterior to the coccyx and 400 to 800 ml. of oxygen or air is injected. The air collects on the side uppermost (Fig. 6), but both sides may be visualized by shifting the patient from side to side following the injection. This procedure is fairly safe, although years ago with deficient technic fatalities with air embolism occurred.

KIDNEY

In general, there is a clearer understanding of the surgical diseases caused primarily by the kidney than those caused by practically any other organ, because the function of the kidney is limited to one important process, namely, excretion of urine. The amount of kidney tissue necessary to carry on the normal excretory function is no greater than one half of one kidney, but the reserve amount of renal tissue is of extreme importance in combating the effects of disease. The amount of urine excreted depends upon the amount of fluid ingested, but on certain occasions a diminution of the amount excreted may definitely signify acute renal impairment. Especially is this true when comparisons of the amount secreted by each kidney are made by ureteral catheterization. The phenolsulphonphthalein excretion test (Rowntree and Geraghty) may be of great value in detecting certain types of disease. Normally the two kidneys should excrete 40 per cent of 1 ml. of a 6 per cent solution of phenolsulphonphthalein within an hour after intramuscular injection. This test is of even greater value in determining the extent of renal damage when the dye is given intravenously with ureteral catheters in place. Normally the dye should appear in the urine from each kidney two to six minutes after injection; at the end of 15 minutes about 15 per cent of the total amount should have been excreted by each kidney. The 15-minute test is more accurate than the hour test.

When renal insufficiency exists in each kidney, there may be a sufficient retention of nitrogenous compounds (urea, creatinin, uric acid) to produce a demonstrable increase in the blood stream. An elevation of the nonprotein nitrogen in the blood (normal of 35 to 45 mg. per 100 ml. of blood) is an accurate method of detecting bilateral renal damage, or a urinary retention, especially the common type produced by prostatic hypertrophy. The nitrogen retention in such instances may be merely an expression of urinary retention in the absence of permanent

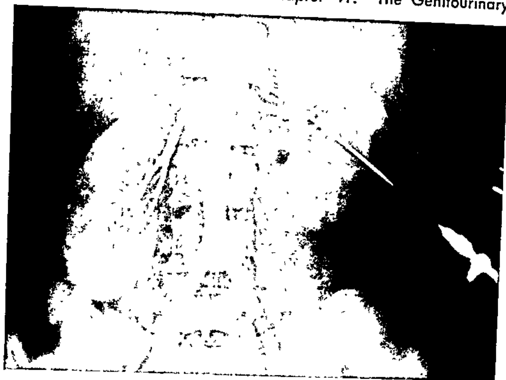


Fig. 4. Kidneys outlined by aortography. Any one of two or three opaque materials mentioned in the text may be used. The kidneys are outlined satisfactorily; no deformities are noted, but right nephroptosis is present.

been very helpful in the diagnosis of renal lesions. Sodium iodide and bromide (Cameron, 1) were originally used but have been largely supplanted by organic compounds of iodine, e.g. hippuran.

Cystoscopic examination includes the visual inspection of the bladder and ureteral orifices, collection of fractional urines, excretory (phenol red) tests, and a variety of roentgenograms in different positions.

6. Intravenous pyelography. The discovery by Von Lichtenberg and Swick (2) that uroselectan (a compound containing 42 per cent iodine by weight), when injected intravenously, is secreted so rapidly by the kidney as to make the urine impervious to the x-ray (Fig. 3) has to a great extent displaced cystoscopic pyelography, because it avoids pain and the occasional reaction (fever, chills) produced by instrumentation of cystoscopy. Various types of organic compounds of iodine, including Diodrast, Hypaque (sodium amedotrizoate), and Urokon (sodium acetrizoate), are used for intravenous pyelography. The adult dose of the three drugs is 7, 15, and 7.5 grams respectively. After a detailed study of the latter two drugs, Jones and associates (Ann. Surg., 73:99, 1956) conclude Hypaque is superior. Although the intravenous method is used as a routine, the retrograde method may be necessary when accurate detail in the pyelogram is needed, e.g., the early stages of tuberculosis and neoplasms of the kidney.

7. Aortography. This procedure was described by Dos Santos (1929) but not popularized then because of the potential dangers associated with it. Injection of 20 ml. of 70 per cent Neo-iopax or 70 per cent Urokon is made directly into the abdominal aorta just above the origin of the renal arteries (Figs. 4, 5). A general or spinal anesthetic is required. X-rays taken after injection are particularly useful in detecting aberrant renal vessels, cysts, and tumors. Evans (3) reports a series of over 1,200 aortograms without a fatality, but renal damage (4) and deaths (5) have been reported. In view of the possibility of complication, most urologists rely upon intravenous or retrograde pyelography and use aortography only on rare occasions (6).

8. Presacral Pneumography. This procedure is particularly useful in revealing the

renal damage, but it is a good criterion for the determination of operability.

Anomalies. Congenital anomalies of the kidney are very common and often produce symptoms. Occasionally the two kidneys are fused together, forming a horseshoe kidney, most often united at the lower pole. One kidney may be small or rudimentary, is frequently displaced (downward) and anomalous in shape (round or mushroom shape). Double ureter and congenital stricture of the ureter are not uncommon. The latter condition is, of course, serious because of its complications (pain, infection, and so forth). On rare occasions, an aberrant artery may be present and by pressure produce a kink of the ureter. Frequently nephroptosis (movable kidney) is present at birth; on other occasions there is apparently sufficient deficiency in the structures supporting the kidney to displace the organ downward later in life. Many of these anomalies produce few or no symptoms and may therefore not be detected except at autopsy or at operation performed for other conditions. Of the manifestations produced by anomalies, pain and urinary infection are perhaps most frequently encountered. Treatment is therefore determined by the symptoms produced; on rare occasions conservative measures fail, and it may be necessary to resort to such radical procedures as nephrectomy. Obviously, nephrectomy should never be performed until it has been established definitely that another kidney is present and is functioning adequately.

Injuries of the Kidney. Although the kidney lies in a protected position adjacent to the vertebral column and above the margin of the lower ribs, it is injured frequently. On most occasions the injury is of a crushing type, although not infrequently it is of a penetrating type (e.g., gunshot injury). There may be no external evidence of injury in the former case, but a history of a blow over the region of the kidney can usually be elicited. The type of injury sustained by the kidney varies from a microscopic tear in the organ to complete division, laceration, or maceration. Degree of destruction, subsequent scar, and urinary leakage are the important points.

The *clinical manifestations* are dependent upon the extent of the injury and upon whether the peritoneal cavity has been entered. Hematuria is the most constant symptom. Microscopic tears may produce no manifestations except hematuria and slight tenderness over the kidney. When the injury is extensive, the patient may present all the manifestations of shock, including tachycardia, low blood pressure, pallor, and weakness. Hemorrhage is no doubt the most important factor in the production of these symptoms. Extravasation of urine of significant amount occurs rather infrequently and adds to the severity of the early symptoms. If the injury to the kidney is associated with a tear through the posterior peritoneum, the symptoms and signs are apt to be more acute because of the increased amount of hemorrhage and the peritoneal irritation. On most occasions, even in the absence of a rupture of the peritoneum, there will be definite manifestations of early peritonitis, including localized abdominal tenderness, muscle spasm, nausea, vomiting, and leukocytosis. These manifestations appear to be caused primarily by direct irritation of important nerves by the retroperitoneal hemorrhage, and not because of the urinary extravasation, because identical findings are encountered frequently in hemorrhage associated with fracture of the spine.

X-ray examination after the intravenous injection of one of the organic iodine compounds mentioned on page 1120 will frequently be of value in revealing the site and extent of injury provided significant escape of urine is taking place.

The *treatment* is likewise dependent upon the extent of the injury. In the absence of severe manifestations, operation is not necessary; the patient may be treated by bed rest, antibiotics, and supportive therapy even though considerable hematuria is present. The spontaneous reparative process in the kidney is considerable, provided the injury is not too severe and has not involved the peritoneum. However, if hematuria is accompanied by marked signs of peritoneal irritation or by a progressive development of shock, it is safe to assume considerable injury to the kidney has been sustained; an operation will therefore be indicated to prevent further bleeding and serious peritoneal extravasation, as well as to repair anatomic de-



Fig. 6. Presacral pneumography following injection of 600 ml. of oxygen. Above, no abnormal findings; K—kidneys and S—spleen. Below, adrenal tumor on right; P—pheochromocytoma, K—kidneys, and S—spleen.

domonas aeruginosa (pyocyaneus) are becoming more frequent (8). Mixed infection is present in 10 to 15 per cent of cases.

Infection may gain access to the kidney in *one of three* ways: 1. the blood stream, 2. by ascending infection, or 3. by way of the lymphatics. Since many of the infections are produced by the colon bacillus, it would appear that on many occasions the organisms are carried to the kidney by the lymphatics which surround the ureter, or by anastomotic channels between the colon and kidney. However, it is probable that an additional factor, i.e., urinary stasis due to obstruction, is necessary before an actual infection develops.

Urinary obstruction, thus, may be responsible for the development of the three main types of infection. Obstruction may be produced in various ways: 1. Calculous obstruction of the ureter (usually at the ureterovesical orifice), or of a calix in the pelvis of the kidney, is one of the most common causes of obstruction. 2. Congenital stenosis at the ureterovesical orifice is a frequent anomaly. 3. A kink may be produced in the ureter by nephroptosis. 4. Anomalies such as double ureter, bifid pelvis, aberrant renal artery, etc., may result in obstruction to the normal flow of urine. 5. Abdominal masses including neoplasms, pregnant uteri, abscesses, etc., may press directly upon the ureter.

The experimental production of hypertension by renal ischemia by Goldblatt (9) and associates has placed an additional responsibility upon the urologists. Numerous clinical reports (Nesbit and Ratliff, 10) are available revealing cure of hypertension following removal of a kidney affected with chronic sclerosing pyelonephritis, proving that renal ischemia was undoubtedly produced by the lesion. Obviously, operative therapy is feasible in such cases only when examination reveals a normal kidney on the other side.

Clinical Manifestations. There is no uniformity in the early symptoms produced by the infections designated as *pyelitis, pyelonephritis,* and *pyonephrosis.* Frequently the onset is sudden, with a chill, fever, nausea, vomiting, and severe pain in the region of the kidney, but radiating downward to the thigh or genitals. On other occasions the onset is insidious, with fever, lassitude, weakness, anorexia, loss of weight, and so forth. In either case there is a tendency for the infection to persist along with the symptoms unless eliminated by proper therapy. The urine contains bacteria and pus cells, usually early in the disease and in large numbers. Frequently, red blood cells are found. Albumin is rarely present in more than slight amounts. Pyelitis is extremely common in young girls. When the infection involves the right kidney and is associated with pain, it may simulate appendicitis; extreme care must be exercised to arrive at a correct differential diagnosis. However, as stated in more detail below, the presence of pus cells in the urine and tenderness over the loin will usually lead to a correct decision. In most instances pyelitis subsides without the development of more than a trivial infection in the kidney parenchyma, and with very little residual change, particularly in young people.

If the infection persists, regardless of treatment, and a hydronephrosis occurs, the cortex gradually becomes destroyed and thinned out and very little urine is excreted. This process may continue until all function ceases and an *autonephrectomy* is established, i.e., the infected organ becomes encapsulated to a great extent by scar tissue and little absorption from the infection takes place. When the function is destroyed to the extent that little or no urine is excreted, pus cells but no bacteria may be found in the urine.

Diagnosis. Examination of the urine is perhaps the most reliable method of establishing a diagnosis. Bacteria and pus cells will be found except in the instances mentioned above. It must be remembered, however, that bacteria and pus cells may be found in various other diseases, including prostatitis, urethritis, etc. A leukocytosis is usually present. Tenderness and, in acute cases, muscle spasm will be demonstrable over the infected kidney. Cystoscopic examination, including inspection of the ureteral orifices, ureteral catheterization, and a search for bacteria in a stained smear of urinary sediment from each kidney obtained by centrifugation, may be of great value in establishing the diagnosis. The amount of urine obtained from the infected kidney and the excretion of phenolsulphonphthalein will be diminished late in the disease, when considerable renal damage is pres-

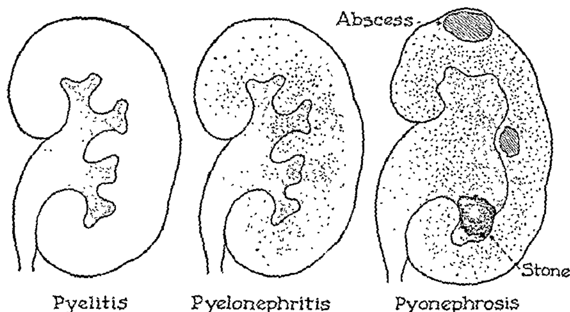


Fig. 7. Drawing to illustrate the three common types of nontuberculous infections of the kidney. From the drawing it appears that the three diseases represent increasingly severe grades of the same process; this, indeed, is true in a large percentage of cases. The term pyelitis is confusing because a certain degree of parenchymal infection undoubtedly exists in most instances of pyelitis, but is of insufficient degree to impair function. In pyelonephritis and pyonephrosis, infections in which the parenchyma is significantly damaged, function may be severely impaired. Stones may or may not be present. A variable amount of hydronephrosis accompanies pyonephrosis.

fects, i.e., lacerations. An incision through the anterior abdominal wall may be advisable because of the likelihood of simultaneous injury to other organs within the abdomen. *Simple lacerations should be repaired by interrupted sutures, whereas severely injured kidneys should be removed, provided the presence of the other kidney is established.* Drainage through a stab wound in the loin should be established to prevent accumulation of urine or bloody fluid. *Failure to operate in the serious cases may allow the development of a perinephric abscess, or if the peritoneum is ruptured, a fatal peritonitis.* For many years it has been known that in patients with a severely damaged kidney the mortality was remarkably lower in those operated upon than it was in those treated conservatively without operation. On the other hand, *in the lesser injuries the patient will recover completely with rest in bed alone.* Therefore, the decision as to operation depends on the extent of the injury as indicated by the manifestations presented by each individual patient.

Infections (Nontuberculous) of the Kidney. The various infections of the kidney may be classified into 1. *pyelitis* and *pyelonephritis;* 2. *pyonephrosis;* and 3. *carbuncle* of the kidney, but such a division is arbitrary and inaccurate since these diseases, with the exception of the latter, on most occasions merely represent various stages in one infectious process (Fig. 7) and are usually associated with obstruction to the urinary flow (7). For example, a persistent pyelitis practically never exists without also a pyelonephritis, except *on occasions when the infection is induced by ureteral catheterization.* The accompanying pyelonephritis may be slight and limited to the central portion of the kidney adjacent to the pelvis. The term pyonephrosis is applied to that type of infection associated with ulceration about the calices, abscesses in the parenchyma, and a thinning of the cortex due to hydronephrosis. *The function of the kidney is least disturbed if the infection is limited primarly to a pyelitis and impaired to the greatest extent in pyonephrosis, in which the loss of function may be complete and permanent.* Years ago the colon bacillus, streptococcus and staphylococcus were the most common causative organisms; however, of recent years, *Aerobacter aerogenes* and *Pseu-*

If no function remains, nephrectomy is performed after acute symptoms have subsided. If adequate drainage cannot be established by ureteral catheterization and the infection is so fulminating as to threaten destruction of the kidney, nephrostomy may be a wise procedure.

Carbuncle of the kidney is the third type of nontuberculous infection; it is commonly of hematogenous origin and pathologically resembles a cellulitis. There is usually a history of a furuncle or carbuncle on the skin several days preceding the onset of symptoms. As would be expected, the causative organism is usually the staphylococcus. The manifestations are much less variable than those of the other types of renal infection already mentioned. Symptoms are insidious and consist primarily of fever, malaise, anorexia, and mild, dull pain in the region of the kidney. Tenderness over the kidney posteriorly is a fairly constant finding and is therefore significant diagnostically. Leukocytosis is usually present. Urine examination may reveal pus cells and erythrocytes but is commonly negative at the onset. The absence of pus cells in the urine is frequently of considerable aid in differentiating this from other types of infections in which pyelitis is the predominating lesion. Treatment is limited to the nonoperative therapy as described above, except when a perinephric abscess is present. Exploration of the kidney may be justified when persistent chemotherapy fails to control the infection and an abscess in the carbuncular infection is suspected.

Perinephric (Perirenal) Abscess. Infection of the perirenal space may be produced by any of several mechanisms, but perhaps the most frequent source is a "carbuncle" of the kidney which in its invasion throughout the cortex finally breaks through the capsule. Frequently it appears that a small abscess, resulting from suppuration in a carbuncular infection, or from a tiny infected embolus, breaks through the cortex. Less commonly, the infection perhaps arises from infected emboli lodging initially in perirenal tissue or results from rupture of a pyonephrosis through the thinned cortex.

The pain associated with a perinephric abscess is variable, is usually located posteriorly in the region of the kidney, but may be so mild as to escape detection by the patient. The pain may be aggravated by bodily movements; the patient and even the physician may thus be led to interpret the pain as originating in the spine. Because of the muscle rigidity, a diagnosis of spinal arthritis or tuberculosis of the spine may erroneously be made. The tenderness posteriorly over the kidney associated with spasm of the lumbar muscles is quite constant, and is significant because of the lack of positive abdominal findings. Fever develops early, is variable in amount, but may be associated with a chill at the onset. Leukocytosis is usually pronounced. Examination of the urine rarely reveals any pathologic findings and is of no diagnostic aid. After the abscess has been present for some time, many systemic manifestations become prominent. Anorexia and nausea are usually present, but vomiting is not so common. The patient becomes weak and pallid, complains of lassitude, and rapidly loses weight. If the abscess increases in size, induration of the deep tissues over the kidney may be demonstrable. On rare occasions the abscess may eventually present anteriorly, thereby masquerading as an appendiceal or liver abscess. The pus may burrow through a small defect in the deep fascia posteriorly and present superficially as a bulging mass (Fig. 8). When this happens, fluctuation is demonstrable, but rarely before; in reality, such a superficial mass is a part of a collar button abscess.

The *treatment* of a perinephric abscess is drainage by operation posteriorly over the kidney as soon as the diagnosis can be made. One or two large cigarette drains are placed in the wound and left in place for five or six days until the abscess cavity is largely obliterated and drainage insignificant. Diagnostic aspiration, if carefully carried out, is occasionally justified in doubtful cases. If possible, the operator should explore for an associated renal carbuncle. Since staphylococcus is the usual organism, penicillin (locally as well as systemically) is a useful adjunct to operation.

Nephrolithiasis. Kidney stones may be composed of any of the urinary components; uric acid, calcium oxalate, and calcium phosphate are common, xanthine and cystine less so. Usually solitary and ovid, the stone, when large, tends to assume the shape of the pelvis

ent, for example, in pyonephrosis or severe pyelonephritis.

Occasionally when a complete block of the ureter occurs, the infected urine cannot enter the bladder; only the clear urine from the other kidney will then be voided. Sooner or later, however, the escape of pus will lead to its detection in the urine; repeated urinalaysis is often necessary, therefore, before making a negative diagnosis of infection.

When considerable pain is present, differential diagnosis between infections of the kidney and such intraabdominal lesions as appendicitis may be difficult. There are several features, however, which should allow one to make the correct diagnosis. For example, the pain associated with a renal lesion usually radiates downward toward the thigh or genitals and the tenderness is confined posteriorly. Fever is present much earlier in the onset of the disease than it is in appendicitis. The presence of fever alone, especially if associated with a chill, will rule out many of the intraabdominal lesions of alimentary tract origin, since they are usually associated with pain and few have chills.

Treatment. One of the most important features in the treatment of renal infections is *chemotherapy*, a procedure extremely valuable in the treatment of urinary infection of all types because these drugs are largely excreted by the urinary route. Numerous drugs are utilized, depending somewhat on the type of infection. The sulfonamides have a wide bacterial spectrum, rarely produce bacteria-resistant strains, and are effective for both bacillary and coccal organisms. The average dose of sulfadiazine is 1 gm. four times daily, and of gantrisin is 2 gm. four times daily.

If sulfadiazine is used, the patient should be given sodium bicarbonate and a copious amount of water, to prevent precipitation of the drug into the kidney. Penicillin is of little value in kidney infection, since its usefulness is limited to staphylococcal, streptococcal, and gonococcal infections (relatively uncommon) and because the majority of staphylococcal strains are becoming resistant to penicillin. Aureomycin is effective against many infections of the kidney, and particularly against *Aerobacter aerogenes*. Of all the chemotherapeutic agents being used at the present time to combat *Pseudomonas aeruginosa* (*pyocyaneus*), polymyxin appears to be most effective (11). However, it is slightly toxic and must be used with care. Terramycin, neomycin, or chloromycetin may be found effective, but tetracycline probably is somewhat more effective. It must be remembered that under therapy with mycin drugs serious micrococcal enteritis will occasionally develop. Again, the value of performing sensitization tests on the organism should be emphasized. On certain occasions when a gram-negative organism is present which resists the usual efforts to control it, sulfathaladine should be given for an interval of several days. Streptomycin and dihydrostreptomycin are useful in coliform and tubercle infections.

Occasionally changing the reaction of the urine appears to be effective in relieving bladder irritation. It may be made alkaline by small doses of sodium bicarbonate (1 to 3 gm. daily) or acid sodium phosphate (1 to 2 gm. daily) or ammonium chloride. In combination with either of the latter two drugs, methenamine in doses of 2 to 3 gm. daily is frequently given because of its effect as a urinary antiseptic. The degree of acidity or alkalinity of the urine can readily be determined by testing the color reaction with selected dyes (12).

When the infection is acute and associated with ureteral obstruction, the insertion of a ureteral catheter is extremely effective in its elimination by establishing drainage. It is frequently difficult to determine whether significant obstruction is present, yet its presence or absence must be determined since ureteral catheterization performed in the absence of obstruction may aggravate the symptoms as well as the infection. Sudden onset of fever and other symptoms, accompanied by severe pain, usually signifies the presence of a urinary obstruction at some point (usually in the ureter). Diagnosis is confirmed if ureteral catheterization reveals a retention of more than a few cubic centimeters of urine in the pelvis of the kidney. Occasionally, it will be advantageous to leave the ureteral catheter in place for two or three days. Bed rest, care of the bowels, and other symptomatic treatment are employed as indicated. Operative treatment is justified only when the function of the kidney is jeopardized or destroyed.

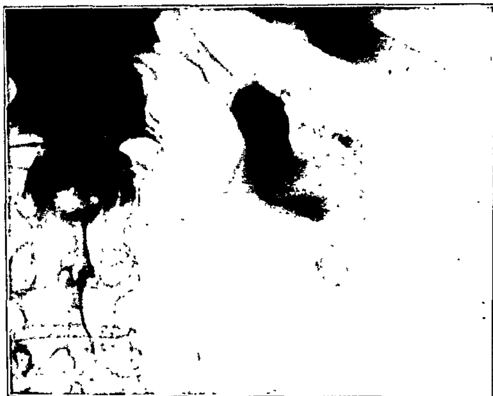


Fig. 9. Roentgenogram, revealing a renal calculus filling the entire pelvis. In this patient the finding was an incidental one; the film was taken only because of a supposed acute injury to the spine. Such stones produce variable manifestations; not infrequently no symptoms whatever are present. Hyperparathyroidism, though a rare disease, is frequently accompanied by stones of this type.

the bladder. The pain is most excruciating and usually radiates toward the thigh or genitals. The stone may pass rapidly into the bladder, often within a few hours, occasionally in two or three weeks, or become permanently lodged near the kidney or at the ureterovesical orifice. Hematuria is a constant finding and is an important sign but is not diagnostic because it is frequently present in such diseases as purpura, hemophilia, and vitamin C deficiency. If the stone is not passed rapidly, infection may develop and pus as well as bacteria will be found in the urine. At least a mild degree of frequency of urination and burning is present. Fever is absent except when obstruction has been present long enough to allow the development of infection. Regardless of the size of the stone, an obstruction to the flow of urine develops at the onset because the impaction produces a total ureteral occlusion. However, as the ureter dilates, the urine may pass around the stone, even though it remains lodged in the ureter. In either case, hydronephrosis develops almost invariably, and if the obstruction to the flow of urine is complete, may be serious because of infection, the development of which is encouraged by urinary stasis. If this condition is not relieved, the hydronephrosis and back pressure in themselves may become so marked as to destroy permanently the function of the kidney. On rare occasions the stone produces sufficient ulceration in the ureter during its passage to lead to stricture formation later on after healing takes place. Differentiation of renal colic from other acute abdominal conditions can usually be made readily by history, urine examination, and x-ray.

TREATMENT. Unless the renal stone is "silent," treatment should be directed toward its removal. Most stones which have entered the ureter will pass spontaneously into the bladder by the institution of conservative treatment such as forcing fluids, sedation, and the like. During severe attacks of colic larger doses of morphine may be required to control the pain, which is controlled most



Fig. 8. Perinephric abscess on the right. Note the bulging abscess which has perforated through the deep fascia and is "pointing" posteriorly. The patient, a 40-year-old male, complained of pain in the back, anorexia, fever, and increasing weakness of three months' duration. No urinary symptoms were present and urinalysis was persistently negative. Incision and drainage were carried out with uneventful recovery; the staphylococcus was isolated from the pus.

and calices. Small stones less than 1 cm. in diameter frequently find their way into the ureter and pass into the bladder.

Little is known of the actual cause of renal calculi, except that on most occasions stasis and infection appear to be important. One type, which is called a "primary stone" (commonly composed of uric acid, calcium oxalate, or urates) occurs in children or young people apparently in the absence of infection or stasis; they are perhaps of metabolic origin. Also metabolic are the large stones, which may be bilateral, seen in hyperparathyroidism (see p. 1069). The so-called "secondary stones," commonly composed of calcium phosphate, are apt to be associated with stasis or infection and may be deposited around a primary stone as a nucleus. Calcification of pre-existing lesions in the kidney has been mentioned as a possible cause (Randall). Prolonged recumbency of spinal cord injury results in stone formation in 25 to 35 per cent of cases (13). Baker and Connelly (14) have recently postulated that nephrolithiasis may be a "connective tissue collagen disease." In 356 cases studied, they noted that 8 per cent of patients with a stone in one kidney have a stone in the other kidney; there was evidence of infection in 43 per cent in patients with bilateral and recurrent calculi.

Clinical Manifestations. The manifestations of renal calculi are extremely variable. In many instances stones are carried in the kidneys for years without producing any symptoms (Fig. 9). More commonly, a mild infection develops in the pelvis about the stone and gradually involves the cortex of the kidney until a severe pyelonephritis develops. If the stone is large, or several are present, the infection may progress to a pyonephrosis, resulting in the ultimate destruction of the kidney. Mild fever, pain, malaise, and anorexia are usually present. Pus, casts, and a variable amount of albumin are present in the urine. Frequency of urination and mild burning pain usually accompany infection of this type. Diagnosis can almost invariably be made by a plain x-ray film since most renal stones contain sufficient calcium to be radiopaque.

The most dramatic manifestation of renal calculi is that spoken of as *renal colic*, which is brought about by the entrance of a stone into the ureter and its passage downward to

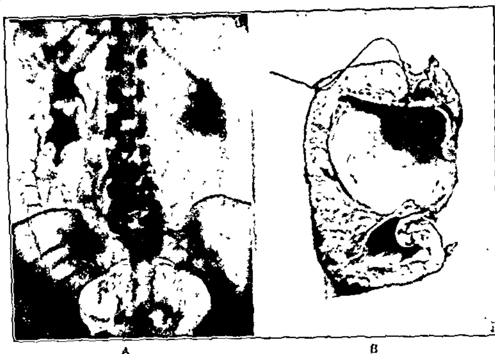


Fig. 10. Hydronephrosis. A, on the patient's right a dilated pelvis with double ureter is noted (after intravenous pyelography). On the left a shadow of a large mass may be observed, but none of the diodrast is passing through the kidney, thus indicating that the function on this side is almost, if not completely, destroyed. Lack of function was corroborated later by intravenous phenolsulphonphthalein with a uretral catheter in place. B, longitudinal section of the excised kidney. Note the thinned cortex and the hydronephrosis which was produced by a congenital stricture at the ureteropelvic juncture. (Courtesy, Dr. J. H. Sanford.)

should be carried out until the source of the obstruction is found.

Treatment should be directed to release of the obstruction which, if acute and complete, demands immediate relief. If the obstruction is produced by a stone in the ureter, such procedures as ureteral catheterization or actual operation are available to remove the calculus, if it is not dislodged spontaneously. Ureteral strictures may be kept open by such a simple procedure as *occasional dilatation* by ureteral catheterization and bougies. Kinks produced by nephroptosis may be *eliminated* by correction of the nephroptosis. Extrinsic pressure due to a tumor may be corrected by excision of the mass. When the hydronephrosis has progressed to the point that function of the kidney is destroyed, nephrectomy may be indicated, particularly if symptoms are manifested.

Nephroptosis. Ptosis of the kidney occurs most frequently in women, almost always on the right side and may be caused by a number of factors. Narrowness of the paravertebral niche, a decreased amount of perirenal fat, emaciation, weakness of the abdominal wall, and so forth, may be mentioned as prominent etiological factors. As stated previously, if the ptosis is sufficient to produce a kinking of the ureter, a hydronephrosis, perhaps with an associated infection, will develop.

Only a small percentage of patients with nephroptosis have symptoms of ureteral obstruction. The most common symptoms are those spoken of as renal colic, consisting of pain in the region of the kidney and perhaps *radiating down the ureter toward the thigh* or genitals. This pain may not be severe but is usually *aggravated by jolting as sustained by* riding in automobiles or streetcars. Frequent and painful urination is not uncommon. Palpation usually reveals tenderness over the kidney. When the patient changes from the recumbent to the sitting position, it is usually possible to demonstrate a shifting in position of the organ downward. If there is doubt about the demonstration of an abnormal *amount of mobility*, pyelographic examina-

promptly when the drug is given intravenously. If, after many days, there is no evidence of progression in the descent of the stone, ureteral catheterization may be instrumental in dislodging it. Occasionally, dilatation of the ureter with a bougie, or several ureteral catheterizations will result in spontaneous passage of the stone. On rare occasions an operation (usually extraperitoneal with incision into the ureter) will be necessary to remove the stone. Large stones in the kidney cannot be passed by way of the ureter and if symptoms are produced, may necessitate operation. This is best done by a posterior incision in the loin and removal of the stone by incision into the pelvis (pyelotomy). The opening in the pelvis is then repaired and the wound closed around a drain. If the function of the kidney is permanently destroyed, nephrectomy is usually indicated after acute infection has subsided. If the stones are present in both kidneys it is usually preferable to operate first on the kidney with the poorer function, since the operation may produce a temporary anuria; if the better kidney is the one operated on first, and this complication (i.e., temporary anuria) results, a fatal outcome may ensue. It has been shown experimentally by Vermeulen and associates (15) that diuresis will tend to dissolve bladder stones, although not enough clinical experience is available to determine how effective it would be in humans. Removal of stones by operation is effective in relieving the patient temporarily, but Abeshouse and Lerman (16) have reported a recurrence rate varying between 11 and 25 per cent in nearly 4,000 operations for stones. They report that when a stone forms in only one area of the kidney (indicating a local causative factor) removal of this area by *partial nephrectomy* reduces the recurrence rate to a very low figure, namely, 2 per cent. However, since the most common cause of renal stones is metabolic, this procedure will be practical in only a small percentage of cases. Baker and Connelly (14) report that treatment with the anti-inflammatory drugs (cortisone, butazolidin, and aspirin) has reduced the recurrence rate in their series by 50 per cent.

Hydronephrosis. Although the dilatation of the kidney pelvis or calices in hydronephrosis is usually caused by obstruction to the urinary flow, it is a fact that in many instances infection appears to be a responsible factor even in the absence of demonstrable obstruction. *Prostatic hypertrophy and stricture* of the urethra may produce hydronephrosis, but the damage inflicted by infection in these instances is more significant than the hydronephrosis. However, in ureteral obstruction "no distensible bladder intervenes to distribute the pressure, and infection is often entirely absent; so that the aseptic dilatation of kidney and ureter progresses rapidly and unobscured." The obstruction may be ureteral and be produced by a variety of causes: 1. stones, tumors, or trauma; 2. kink of the ureter due to nephroptosis, congenital malformation (megaureter with or without stricture); and 3. extrinsic pressure (aberrent vessels or tumors).

As the hydronephrosis progresses the cortex becomes thinned and function impaired (Fig. 10), but not to a degree proportionate to the thinning of the cortex. On many occasions the cortex may be nothing more than a mere shell; yet there may be few if any demonstrable manifestations of impairment of renal function. A sudden complete obstruction produced by a stone or by accidental ligation of the ureter may diminish the function to zero and produce irreparable damage in as short a time as one week, whereas a partial obstruction may exist for months with little impairment of function.

The *clinical manifestations* of hydronephrosis are variable. On many occasions a pronounced dilatation of the ureter and kidney pelvis may develop before sufficient symptoms are produced to bring the patient to a doctor. Mild pain in the region of the kidney, radiating downward along the ureter is a common complaint. Tenderness over the kidney posteriorly is usually present. The dilated kidney may or may not be palpable anteriorly. Fever may or may not be present, depending largely upon the amount of infection. If the obstruction is sudden and complete, or nearly so, acute symptoms (renal colic) as described previously in this chapter will be produced. Diligent effort must be made to find the cause of the hydronephrosis. Ureteral catheterization, pyelography, x-ray, or examination of the prostate and urethra,

such as frequency of urination and severe dysuria, are apt to develop. The urine becomes cloudy because of the pus contained in it, and frequently is smoky or red because of hemorrhage in the pelvis. Pain in the region of the kidney is not uncommon and is occasionally colicky, but never severe. Mild tenderness over the kidney may or may not be present. Examination of the urine reveals pus in large quantities, a variable amount of red blood cells, albumin, and casts. Cystoscopic findings, including ulcers in the bladder, reddening, ulceration, and retraction of the ureteral orifice, are fairly diagnostic of the disease. Pyelograms reveal irregularities in the shadows of the calices with narrowing, or clubbing, and a contraction of the pelvis with irregular constrictions and dilatation of the ureter. The excretion of phenolsulphonphthalein by the affected kidney is diminished, but not early in the disease. The diagnosis is confirmed by finding tubercle bacilli on smear or by culture, or by reproducing the disease by guinea pig inoculation.

TREATMENT. Since effective antibiotics have been found for tuberculosis, therapy has become much less radical. Nesbit and MacKinney (17) recommend complete rest in a sanitorium giving dihydrostreptomycin, 2 gm., and para-aminosalicylic acid (12 to 15 gm.) daily. Isoniazid is recommended in addition, if a second course is needed. In unilateral disease they recommend antibiotic therapy for 60 days. If improvement is not substantial, nephrectomy is performed and antibiotics continued for another 30 days. If the disease is advanced initially, they recommend nephrectomy after 10 days of antibiotic therapy. Before nephrectomy is done, it must be established (by pyelography and the like), that the opposite kidney is sufficiently healthy to sustain life. It is always important to examine the patient carefully for the possible existence of an active lesion elsewhere (particularly lung and bone). Nephrectomy should not be performed if such an active lesion is found. Removal of the kidney may be technically difficult because of the large amount of dense perirenal scar tissue. On account of the involvement of the ureter it is usually advisable to remove all of it, even though it may be necessary to do it through another incision at a later date. Partial nephrectomy is occasionally advisable. Ulcerations in the bladder heal rapidly following nephrectomy unless the remaining kidney is infected. Hygienic measures, such as rest, large amounts of wholesome food, and so forth, are important in the convalescence.

Tumors and Cysts. The great majority of the neoplasms in the kidney are malignant; few are benign. An enormous amount of confusion exists as to their classification. However, most authorities do not accept the hypothesis proposed by Grawitz in 1883 that clear cell carcinomas were adrenal rests, but prefer to classify renal tumors as 1. tumors of the adult renal parenchyma, 2. tumors of the renal pelvis, and 3. tumors of the kidney in childhood (Wilm's tumor). Adenocarcinomas are the most common renal tumors, constituting about 80 per cent of the total. Dodson (18) classifies these tumors as 1. papillary adenocarcinoma, (*a*) with clear cells, (*b*) with granular cells; 2. malignant cystadenoma; and 3. alveolar carcinoma.

ADENOCARCINOMA. Papillary adenocarcinomas with clear cells constitute the largest group. On cross section they have a yellowish appearance, often revealing hemorrhage and necrosis. On section the cells are large, cuboid, and clear, resembling carcinomas arising from the adrenal cortex (Fig. 12). In general, these tumors grow more slowly than other carcinomas of the kidney.

Hematuria, although not constant, is the most common symptom and is manifested early when present. It is usually sufficiently severe to be detected by the patient. The bleeding is painless unless it occurs in such large quantities as to form clots and produce renal colic. Mild pain in the region of the kidney may be present but is rarely noted before a tumor is palpable. The function of the kidney is rarely impaired until the terminal stage. Except in rare instances, pyelography reveals an abnormal "filling defect" in the x-ray. Occasionally the tumor remains small and produces such few symptoms that metastases (usually to the brain, lungs, or bone) may occur and produce symptoms before the local tumor does.

Nephrectomy is the treatment of choice unless metastases are present or the opposite kidney is severely diseased. The five-year sur-

tion should be resorted to, and roentgenograms of the kidney taken in the recumbent and standing position. If distention of the kidney pelvis by retrograde pyelography reproduces the pain complained of, it is reasonably presumptive that the kidney is the cause of the pain. Intravenous pyelograms during an attack of pain may reveal hydronephrosis although the pyelograms may be normal when the patient is having no pain. If replacement of the kidney to its normal position by recumbency and maintenance there by a "kidney belt" relieves the pain, the evidence is still more conclusive that renal ptosis is the cause of the patient's complaints.

Treatment should be directed toward improvement in the general health. It is important that the patient gain weight so as to increase the amount of perirenal fat. Frequently, correction of faulty posture will shift the abdominal organs so as to make more room for them in the upper abdomen. A wide abdominal support or elastic belt (with or without a "kidney pad") frequently relieves all symptoms, because of the support given the abdominal organs. Nephropexy, that is, fixation of the kidney in its normal position by operative means, is performed occasionally with variable success.



Fig. 11. Tuberculosis of the kidney (Longitudinal section after operative removal). Note the ulceration surrounding the calices. Abscess formation is common and may at times destroy practically the entire cortex. (Courtesy, Dr. D. K. Rose.)

Tuberculosis of the Kidney. Tuberculous infection of the kidney (Fig. 11) is a disease of early adult life and is primarily unilateral, but in 10 to 25 per cent of the cases both kidneys are affected. The organisms reach the kidneys by way of the blood stream. Usually a primary focus can be found elsewhere, most often in the lungs, but frequently no primary lesion can be demonstrated. The infection starts usually at the base of the papilla in the lower or upper pole of the kidney and may spread by the lymphatics so that several foci will be produced within the organ. A toxic nephritis of the parenchymatous type may develop in the opposite kidney as well as the diseased organ. The large amount of albumin and casts found so frequently in the urine collected from each ureter is explained by this complicating lesion. As the disease progresses and involves the bladder, the opposite kidney may become infected, usually by ascending infection.

The lesion progresses slowly, healing by scar tissue in isolated areas. This scarring gradually produces a shrinking of the kidney and a contraction of the pelvis. The infection may spread by caseation or cavitation until ulcers appear in the pelvis after which the ureter is obviously exposed to the disease. Sooner or later the infection becomes implanted in the ureter. Peristalsis is lost early. Ulceration leads to scarring of the wall of the ureter, thereby producing strictures at numerous points and a shortening of the ureter. If the fibrosis in the kidney progresses to the point that the arteries become obliterated, an autonephrectomy will be produced.

Clinical Manifestations. The symptoms produced by tuberculosis of the kidney are so insidious that the disease may be present for weeks or months before the patient is aware of it. Frequently, systemic symptoms, such as fever, malaise, anorexia, and loss of weight, are the first noted. On other occasions, frequency of urination caused by secondary invasion of the bladder is the first complaint. Sooner or later, in untreated cases the bladder becomes infected. When this occurs, troublesome symptoms,

of pain produced by the tumor is minimal, the tumor is usually very large before it is detected. If metastases have not taken place and the size of the tumor permits, nephrectomy should be performed. The tumor is so sensitive to x-ray therapy that many surgeons advise x-ray therapy preoperatively on the basis that a large inoperable tumor may be made operable. However, the authors agree with Gross (19), who advises against this, on the basis that metastases may take place while waiting for radiation effect. Prognosis is poor.

Polycystic Kidney. Multiple cysts of the kidney are usually bilateral and are presumably of congenital origin, although symptoms may not be produced until late in adult life. They appear to be hereditary as suggested by the fact that frequently more than one member of the family is affected. The cysts contain thin or gelatinous amber-colored fluid, not urine. There is usually a large amount of fatty tissue deposited about the organ. Surprisingly little renal tissue is demonstrable, even on cut section.

Except for hematuria, which may be present early in the disease, the symptoms are those of nephritis, although usually insidious; rarely do these patients live to be over 40 or 45 years of age. Albumin and casts are demonstrable in the urine. Polyuria may be present. One kidney usually increases in size faster than the other and may or may not be palpable. Diagnosis can be confirmed readily by pyelography because of the lengthening and distortion of the calices.

Since both kidneys are usually involved, treatment is rarely surgical. Occasionally, suppuration develops within the cysts, thereby demanding drainage or nephrectomy.

Solitary Cyst of the Kidney. Such cysts are practically always unilateral but may attain considerable size. The fluid within the cyst is clear and amber colored or hemorrhagic, but not urinous. Mild pain in the region of the kidney may be complained of when the cyst becomes large. Frequently they may attain a size large enough to be palpable through the abdominal wall without producing any symptoms. Treatment consists of excision of the cyst with repair of the defect; rarely is nephrectomy indicated. These cysts very frequently may be wiped out of the kidney with a gauze sponge.

BLADDER

Reference has already been made to surgical procedures performed upon the bladder (cystostomy for stone) in ancient times, but a clear understanding of the physiology of the bladder and the types of disease affecting it was not possible until the invention of the cystoscope. The bladder is innervated by autonomic fibers comprising two separate nerve tracts: 1. fibers from the second dorsal to the third lumbar anterior roots constitute the sympathetic innervation and permit filling of the bladder by maintaining contraction of bladder neck and relaxation of the wall; 2. pelvic nerve fibers arising from the second and third sacral roots constitute its parasympathetic innervation and are important in emptying the bladder since stimulation of this group of nerves causes contraction of the bladder wall and relaxation of the bladder neck. In 1927 Rose (20) introduced the use of the cystometer, an instrument designed to measure bladder pressure and capacity, and their relation to pain, desire to void, and so forth. This instrument opened up an entirely new field for the study of the physiology of the bladder and the diseases affecting it. A curve (cystometrogram) obtained by these studies is not specifically indicative of disease, but is in reality a graph of the individual patient's bladder muscle reaction when the bladder is filled with fluid (Fig. 13). Such data (i.e., the sensation produced by various amounts of fluid) allow the clinician to determine the cause of various types of frequency, urgency, and incontinence. Thus, treatment can be based on actual bladder physiology.

Congenital Anomalies. *Exstrophy of the bladder* is an exceedingly distressing congenital deformity in which exposed bladder mucosa lies open on the anterior abdominal wall. It occurs most often in males, but fortunately is rather rare. The defect is explained by a failure of the symphysis pubis and the abdominal wall just above it to unite in the midline. The roof of the bladder is absent; the floor of the bladder including the trigon protrudes outward. The penis and scrotum are small. The prostate and seminal vesicles are atrophic or absent. The escaping urine

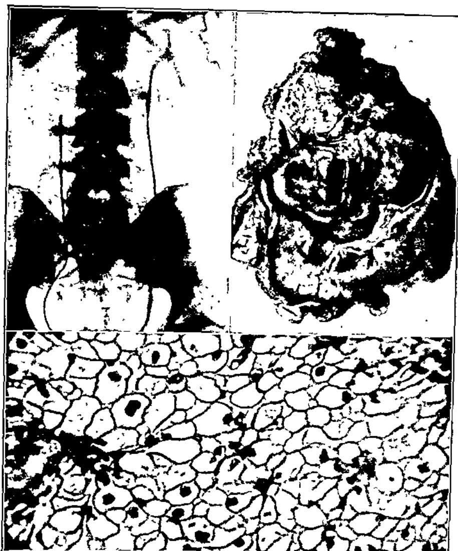


Fig. 12. Clear cell adenocarcinoma of the kidney (hypernephroma). Upper left, pyelogram (per ureter) of the left kidney shows elongation and narrowing of the upper calyx, thus indicating a tumor in this portion of the kidney. The patient had pain in the region of the left kidney, and hematuria of four months' duration. Upper right, photograph of a longitudinal section of the kidney after operation. The tumor involves the entire upper portion of the kidney and has filled the pelvis much more than the pyelogram indicates. Below, high power photomicrograph of the tumor, revealing the "foam" cells with very little connective tissue stroma. (Courtesy, Dr. J. H. Sanford.)

vival rate for adenocarcinoma of the kidney is about 30 per cent.

EPITHELIAL TUMORS OF THE RENAL PELVIS. These tumors are usually of papillary type and may be either benign or malignant. In either case the papillary or warty growth may grow profusely and completely fill the pelvis and even extend down into the ureter. Hematuria is the predominating symptom. Nephrectomy should be performed if possible.

EMBRYOMA OF THE KIDNEY (WILMS' TUMOR). This tumor is sarcomatous in type but contains many embryonal structures, including connective tissue, cartilage, muscle, and abortive renal elements. Spindle and polyhedral cells along with epithelial tubules usually constitute the major cellular elements. It is encountered only in children, rarely after the age of 10. The tumor attains a huge size, has a greater tendency to remain encapsulated than most malignant tumors, but may metastasize through lymphatics as well as the vascular system (including the wall of the renal vein). Like other renal tumors, the only early symptom is hematuria. Because the amount

fracture of the pelvis, the jagged bone edges may tear or perforate the bladder. A moderate blow over an overdistended bladder may cause a rupture, but spontaneous *rupture of the bladder* because of overdistention is exceedingly uncommon. Traumatic rupture is occasionally associated with fractures of the pelvis; it occurs most frequently when the bladder is full and therefore is relatively more common in drunken people. Unless the patient is drunk or unconscious, there is invariably considerable pain at the time of rupture. On the other hand, since sterile urine often excites only mild irritation of the peritoneum, very few symptoms and signs may be manifested, and the diagnosis will be missed. Peritonitis due to associated infection is apt to occur ultimately (unless prevented by early repair) and adds greatly to the seriousness of the situation. Mild shock may be present because of associated hemorrhage. Tenderness over the bladder is constant, but variable in intensity. Diffuse abdominal tenderness, muscle spasm, and other signs of peritoneal irritation, such as nausea and vomiting, may be present. Of most diagnostic importance is the inability to void. If rupture of the bladder is suspected, and the patient is unable to void, catheterization (using strict aseptic technic) should be performed; if perforation exists, rarely will more than a few cubic centimeters of bloody urine be obtained. Diagnosis is further confirmed by obtaining a cystogram using about 200 ml. of 15 per cent Urokon solution.

Treatment is obviously surgical, consisting of celiotomy with repair of the laceration as soon as the diagnosis is made. To prevent leakage at the suture line because of distention, it is necessary to insert a retention catheter and leave it in place for several days.

Rupture of the bladder is quite common in the explosions of war. Immediate operation is, of course, indicated, but performance of cystostomy is more imperative than in civilian injuries.

Cystitis. The term cystitis correctly used refers to an infection of the bladder, usually but not always accompanied by dysuria, i.e., frequency and pain on urination. On the other hand, the term cystitis is often used, perhaps incorrectly, in patients with the same symptoms, due not to infection of the bladder itself but to other causes, e.g., Hunner ulcer or urethritis.

Infection of the bladder occurs as a primary disease; also, it may be secondary to infections of the kidney. Of the other factors which may be responsible for cystitis, the following should be mentioned: prostatitis, residual urine, hyperplastic epithelial changes, tumors, and contamination from catheterization. The bacillus coli, tubercle bacillus, staphylococcus, streptococcus, and proteus bacillus are the organisms most commonly responsible for infection. The disease occurs in either the acute or the chronic form. The bladder mucosa is reddened and edematous. Ulcers are not uncommon.

Because of the danger of production of infection by catheterization, such a procedure should be performed only when necessary, and only with strict aseptic technic. Especially is this true when a residual urine, tumor of the bladder, hypertrophy of the prostate, calculus, or neurogenic lesion is present. Cystitis in the presence of such lesions is apt to be especially serious.

CLINICAL MANIFESTATIONS. The most significant symptoms are frequency and burning on urination. There may be severe pain at the end of urination because of the excessive contracting efforts of the bladder to empty itself. Pus cells are always found in the urine, frequently in such large quantities as to make the urine cloudy; red blood cells are not uncommon. Cystoscopy will reveal a reddened, edematous mucosa, perhaps with ulceration.

In tuberculous cystitis the depression of the ureteral orifice ("golf ball ureter") noted in cystoscopic examination may be the most diagnostic finding. The edema and redness are most commonly found in the trigon where the ulcerations produced by the miliary tubercles are likewise most frequently encountered. The symptoms and urinary findings in tuberculous cystitis are similar to those just mentioned except that with proper technic the tubercle bacillus can frequently be found in the urine.

The *treatment* of cystitis consists chiefly of elimination of the primary source of the infection, an achievement which often can be accomplished only when a urinary obstruction is relieved. Rarely does a cystitis fail to subside readily when the offending focus is

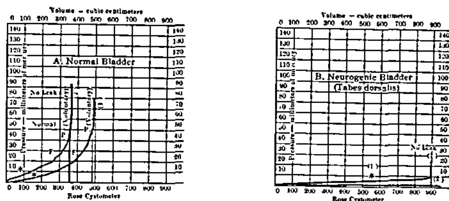


Fig. 13. Diagnostic charts obtained with the Rose cystometer. A cystometrogram is obtained by introducing sterile water through the cystometer into the bladder of the supine relaxed patient. The graphs, as exemplified above, record pressure changes against volume and also the sensations of the patient, e.g., first desire to void is indicated by an asterisk (*), a sense of fullness is shown at "F" and of pain at "P." Note that two consecutive superimposed graphs are obtained at each examination in order to stimulate the stretch reflex and to measure the strength of the bladder wall. (Modified from Rose, D. K. J. Urol.)

must be drained into a special type of cup or be absorbed by dressings. Sufficient urine escapes, however, to produce irritation and maceration of the skin about the defect. The floor of the bladder becomes infected and presents a red, beefy appearance. Infection ascends readily up the ureters and is instrumental in causing the death of two thirds or three fourths of these poor unfortunates before they attain the age of 18 or 20.

The most popular method of the past few years consists of the transplantation of the ureters into the sigmoid, preferably in two stages (one ureter at a time). This operation meets with the most success if not performed before the age of seven or eight. Transplantation of the ureters obliquely through the wall of the sigmoid, as originally suggested by Coffey to avoid ascending infection, is being abandoned because it appears that obstruction to urine flow into the sigmoid is more likely to cause renal infection than ascending infection (21, 22). A more direct anastomosis with as large a stoma as possible is, therefore, preferable to the Coffey technic. The bowel should be prepared a few days before operation by oral administration of sulfathalidine or streptomycin. Heavy chemotherapy with penicillin and streptomycin intramuscularly should be carried out for several days postoperatively. During the past few years the Bricker method (23) consisting of the construction of an artificial bladder from a segment of ileum is gaining favor; by this method the urine is drained continuously to the outside and is collected in a Rutzer bag or its equivalent.

A *diverticulum* is a common defect thought by some to be congenital in origin, but in reality it is usually associated with urethral obstruction (especially prostatic) of some type. Bladder diverticula may vary in size from a tiny saccule, which is not visible on the exterior of the bladder, to a defect which is larger than the bladder itself. They occur most often on the posterolateral wall, and as they increase in size may pull the trigon into the defect. There may be no symptoms of the diverticulum itself; however, frequency or burning on urination, difficulty in urination, etc., may be present because of the obstruction and infection. The infection may be secondary to stagnation of urine in the diverticulum or to the urinary (e.g., prostatic) obstruction. Treatment is directed toward eradication of the infection by irrigation of the bladder and relief of the urethral obstruction. If the diverticulum is large, it is usually advisable, however, to remove it surgically, because of the liability to reinfection. This is not a simple and innocuous procedure and should not be attempted by one not skilled in urologic surgery; postoperative care, including the use of a retention catheter, is likewise important.

Injuries of the Bladder. Because of the protected position of the bladder within the pelvis, injury is uncommon except when produced by fracture of the pelvis or penetration by bullets. When a patient sustains a severe

is more common in the malignant tumor, as is also cystitis and calcareous encrustation. Hematuria may be the only symptom except for burning and frequency of urination incited by infection. On rare occasions, bits of tumor break off and are passed in the urine or actually produce urethral obstruction. Fulguration, implantation of radium seeds or needles, and x-ray therapy constitute the chief procedures in the treatment, and are fairly efficient in effecting a local disappearance of the tumor. Because of the involvement in the base of the bladder, resection of the bladder is rarely indicated since transplantation of the ureters into the colon (a formidable procedure in these patients) must also be done.

CARCINOMA. In addition to the malignant papilloma there is another type of malignant growth designated as carcinoma, which is a squamous cell tumor, appearing as an ulcerating, elevated thickening of the bladder wall. The symptoms encountered are similar to those produced by the papillomatous tumors. For tumors in the dome of the bladder, local resection is appropriate. When the neoplasm is located near the trigone, total cystectomy with transplantation of the ureters will be necessary. However, Dean (24) has shown that in 40 per cent of cases the kidney shows damage (by pyelography) within six months following ureterosigmoidostomy. In view of this complication, which has been appreciated by most urologists, the operation is being modified by construction of an artificial bladder from the colon (25, 26) or ileum (23). However, the follow-ups in total cystectomy are disappointing; Marshall and Whitmore (27) noted that of 100 patients having ureterosigmoidostomy, only 37 were alive two years later.

Retention of Urine. Urinary retention occurs most commonly as a complication of operations, particularly those about the pelvis and perineum.

The difficulty in urination is made more acute by the recumbent position of the patient. Before resorting to catheterization, all possible effort should be made to assist the patient in voiding, particularly because repeated catheterizations may lead to cystitis. Such simple procedures as a warm water douche of the genitals and the psychic effect of turning on a water faucet in the patient's room may enable the patient to void. Enemas are frequently effective in inducing sufficient relaxation of the urinary sphincter to allow the patient to void. Now that we know that early ambulation is not only harmless, but is actually beneficial, whenever possible the patient may be allowed to sit or stand beside the bed to void, if unable to do so in bed. If retention is due to pain in a perineal wound, a small dose of morphine may be of aid in voiding. Carbachol (carbamylcholine chloride) in a dose of 0.25 mg., repeated in one-half hour if necessary, usually is effective in promoting urination. If the above measures fail, catheterization must then be done (Fig. 14). In general, catheterization should not be delayed until the bladder distention is pronounced, since only rarely is the patient able to void when distention with pain has been present longer than an hour or two. Moreover, a bladder which has been subjected to considerable distention is much more liable to become infected. In any event, extreme care, utilizing perfect aseptic technic, must be exercised during catheterization; no part of the catheter which is to be inserted beyond the meatus should be touched except with a sterile instrument or the sterile gloved hand. Gentleness is likewise important. Following catheterization the patient should be encouraged to void in a few hours, before sufficient urine has accumulated to produce pain. If difficulty is still experienced in voiding, catheterization should be repeated in eight or ten hours, because the normal mechanism is usually regained more rapidly than it is if one waits until distention develops to the point of pain. Intermittent catheterization is unwise when a definite obstruction is present and remains. Under such circumstances it is preferable to insert a retention catheter, although frequently suprapubic cystostomy may be indicated.

Following certain operations, e.g., resection of the rectum, retention of urine may persist for many days; it is assumed in such instances that the retention is not due to simple reflex spasm, but to actual division of the pudic nerve which supplies the bladder. Numerous other conditions produce retention of urine in addition to other disturbances in bladder function; the term neurogenic bladder is applied to such cases.

removed, regardless of whether or not the infection is tuberculous. Fluids should be given in large quantities. Sedatives may be necessary because of the pain, especially in tuberculosis. When the urine is highly acid, the burning and frequency on urination may sometimes be relieved by the administration of alkalis, such as sodium bicarbonate or citrate. Irrigation of the bladder once or twice daily with a 1:5000 solution of potassium permanganate, followed by instillation of a few cubic centimeters of 10 to 20 per cent solution of argyrol after irrigation of the bladder may be helpful. Chemotherapy is indicated, but only after the organism is isolated and its sensitivity to the various chemotherapeutic agents is determined.

Bladder Calculus. Stones in the bladder usually occur singly but may be multiple. Most of them are comprised chiefly of urates (descending from the kidney), but uric acid, phosphate, and oxalate stones are also encountered. There is usually sufficient calcium present to make the calculi impervious to the x-ray. Vesical stones are encountered most commonly in men, less frequently in children, but rarely in women except in hyperparathyroidism. The size is variable; on rare occasions they may be 2 inches or more in diameter. Frequently, stones originate from small calculi from the kidney and form primarily in the bladder; they may develop around a foreign body.

The *symptoms* include burning and frequency on urination, but the type of pain occurring in the perineum, radiating to the head of the penis and accentuated by activity of the patient, is more diagnostic. Pain is frequently severe at the end of urination when a few drops of bloody urine are occasionally observed. On rare occasions the stream is stopped suddenly by the stone lodging in the prostatic urethra. Infection is a frequent accompaniment of stones.

The *diagnosis* may frequently be made by contact of the stone with a sound, but the x-ray and cystoscope constitute much more reliable means of making a diagnosis. The urate stones, however, are occasionally radiotranslucent so that diagnosis cannot be confirmed by x-ray.

The *treatment*, of course, consists of removal of the stone. If the calculus is small, it may frequently be removed readily by litholapaxy; i.e., crushing with a lithotrite introduced through the urethra and removing the fragments by irrigation. If the stone is large or too hard to crush, or if obstruction due to urethral stricture or prostatic enlargement prevents the passage of the instrument, it will be necessary to open the bladder in order to remove the stone. The bladder is frequently left open to drain through the suprapubic opening, but rarely is it unsafe to close it, providing a retention catheter is placed in the urethra and allowed to remain for a few days.

Foreign Bodies in the Bladder. It is not uncommon to find foreign bodies, such as hair pins, pieces of rubber, and catheters, in the bladder, introduced by sexual perverts. Not only do these foreign bodies produce infection, but with few exceptions they act as the nucleus for the formation of stones.

Tumors. Neoplasms of the bladder may be either benign or malignant but with few exceptions can be classified into one of three types.

BENIGN PAPILLOMA. Benign papillomas are encountered most commonly in males, previous to the age of 45. They appear usually in the base of the bladder and may be single or multiple. The tumor grows insidiously and no doubt is commonly present months or years before symptoms are produced. Frequently, the growth is responsible for the development of an infection (cystitis). On rare occasions calcareous encrustations are found on the papillomatous strands. Ulceration is not common. Perhaps the most common manifestation is hematuria, occurring usually at the end of urination. Such tumors are best treated by fulguration through a cystoscope. On rare occasions it may be necessary to resort to excision by cystotomy.

MALIGNANT PAPILLOMA. This tumor is not unlike the benign papilloma in appearance but occurs, for the most part, in older people (usually males). It arises most commonly in the trigon, but there is a greater tendency toward multiplicity of foci or implantation of growth than in the benign tumor. The microscopic appearance of the base of the tumor is the determining factor in the differentiation between the benign and the malignant growths. Metastasis occurs slowly. Ulceration

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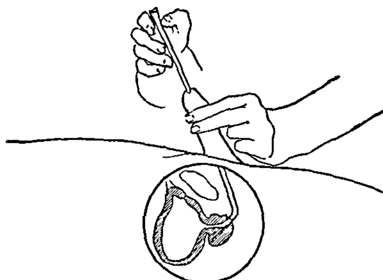


Fig. 14. Technic of catheterization in the male. Note the sharp curve made by the membranous and prostatic urethra; this angulation adds to the difficulties of catheterization, particularly when enlargement of the prostate is present.

Neurogenic Bladder. The term neurogenic bladder refers to disturbances in urinary function which are not due to disease of the urinary tract but to disease, injury, or abnormal function of the nerves supplying the bladder. The disturbances produced by neurogenic factors vary greatly and are often associated with or complicated by other lesions, inflammatory or neoplastic. Strictly speaking, any variation in bladder function from the normal is classified as neurogenic when the primary factor lies in the central nervous system. When the abnormal function is secondary to changes in the bladder wall, induced by trauma, prostatic or other obstruction, and the like, the term myogenic bladder is used.

The disturbances in bladder function which are of neurogenic origin may be either hypotonic or hypertonic. Of the first group, the etiologic factor is usually tabes, or occasionally trauma; reflex causes following rectal and pelvic operations especially are frequently responsible for a hypotonia bladder. In The hypertonic type, irritative lesions play a great role, such as neuritis, some spinal cord tumors, spinal meningitis, and so forth. To understand the mechanism of production of these types of bladder disturbances, it is necessary to have a clear understanding of the physiologic mechanism of the bladder.

The function of the bladder is divided into that exerted by the bladder wall (expulsive force) and that due to the sphincter control (the "lock"). The latter mechanism is made up of the internal sphincter, which is but a thickening of the circular muscle layer of the bladder wall, and the external sphincter, which consists of the muscle in the urogenital trigon and is influenced in its action by the anterior part of the levator ani. When the posterior roots of the spinal cord are diseased as in tabes dorsalis, an atonic bladder results; in diseases such as spina bifida, in which both anterior and posterior roots may be damaged, marked retention with low intravesical pressure and increased bladder capacity is apt to be present.

The autonomic nerve supply to the bladder contains both sympathetic and parasympathetic fibers from the standpoint of function; however, this is difficult to demonstrate anatomically. Actually, all three types of impulses (pain, stimulation, and inhibition) are carried by the autonomic nerves supplying the urinary bladder. These fibers are carried in the parasympathetics of the second and third sacral roots and in the sympathetics arising from the second dorsal to the fourth lumbar roots. This wide distribution explains the imperfect results when merely the presacral nerve is resected in attempt to relieve pain in the bladder and to decrease its capacity. The

occurrence of pain in itself may be primarily responsible for inhibition of normal contraction of the bladder wall, and thus produce retention of urine. Such cerebral inhibition is, of course, a normal impulse; in neurogenic bladders, however, it has a great clinical importance since suddenly impaired cerebration (organic or functional) may cause its release and thus produce incontinence. On the other hand, augmentation of this inhibitory influence as by fear, etc., may produce urinary retention (psychic retention). Postoperative retention is intimately tied up with inhibition, being partly due to the fear of initiating the act of voiding, particularly in pelvic and rectal operations; reflex spasm of the sphincter may also be important.

CLINICAL MANIFESTATIONS. The manifestations produced by a neurogenic bladder vary considerably with the type of disease responsible for it. As already indicated, two groups of disturbance are recognized, hypotonic and hypertonic; both types, however, may play a part in the symptomatology in a particular patient. *Incontinence* (involuntary urination) is an important clinical manifestation and implies an inability of the patient to control the voiding act. When it occurs during sleep, it is called enuresis. It may be associated with a retention of urine, i.e., the bladder may be dilated to capacity and small amounts of urine will dribble through the urethra constantly; this is an undesirable situation because of the increased danger of infection. *Frequency* of urination is most often due to organic disease (e.g., urethritis and cystitis) but may also be due to abnormal impulses carried by the autonomic nerves. *Pain* is present when retention is associated with a hypertonic state of the musculature. *Inability to void,* whether associated with pain or not, is likewise most often due to organic obstruction (enlarged prostate, and so forth); if due to neurogenic factors, it is produced by either a paralysis of the expulsive power of the bladder or a failure of the sphincters to relax. *Lack of desire to void* is distinctly a manifestation of a neurogenic bladder and is associated with marked *retention of urine*. Retention of urine is objectively manifested by the demonstration of increased bladder dullness but more certainly by catheterization. If other lesions are present or if catheterization has induced an infection, the manifestations due to neurogenic factors will obviously be complicated. The data furnished by the cystometer (Rose and others) give considerable information as to the type of neurogenic disturbance which is present; thorough physical and especially neurological examination will usually reveal the true nature of the disease responsible for the urinary abnormalities.

TREATMENT. Obviously, therapy depends on the type of disturbance present. Retention of urine due to reflex causes has already been considered. When tabes dorsalis is responsible for the retention, catheterization is used as necessary; on account of the low intravesical pressure, little damage to the kidney due to the pressure is sustained. Hence, bacterial contamination is less likely to lead to serious infection of the kidney. In the hypertonic bladder with retention, however, catheterization is less permissible because of the likelihood of the production of infection.

In the case of spinal cord injuries, the problem of treatment is more difficult because of the sudden development of the disturbance which is in most cases due to an inability to void, incontinence, or retention. It may be difficult, moreover, to estimate accurately the seriousness of the cord damage.

In general, there is much disagreement among urologists as to the treatment of this group of neurogenic bladders, sustained, for example, by injury to the spinal cord. It is agreed, however, that attempt should be made to produce an "automatic" bladder by effecting evacuation through the mechanism of massage of the bladder at regular intervals, four to eight times per day. In a large percentage of cases an automatic bladder, which will empty itself fairly completely with stimulation or effort on the part of the patient, will be developed. If this fails, tidal irrigation arranged in a manner similar to that described by Munro (28) may be instituted (Fig. 15). Less preferable is a retention catheter. Most urologists believe that a retention catheter or a suprapubic cystostomy is preferable to frequent catheterization.

If infection develops with the conservative methods and in spite of chemotherapy, a retention catheter or suprapubic cystostomy may be necessary. Transurethral resection of the vesical neck is often effective in eradicat-

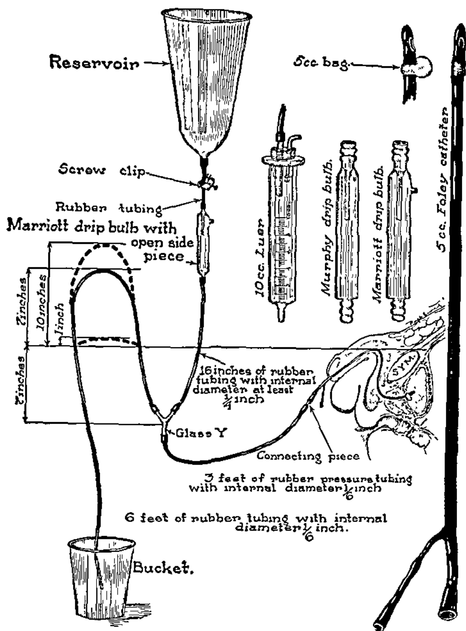


Fig. 15. Apparatus for continuous tidal irrigation. (Modified from Lawrie-Nathan, 1939.) Either a 10-cc. Luer syringe or a Murphy or Marriott drip bulb, as illustrated, may be used to provide a continuous drip. *An air vent is essential in this unit. 60 drops per minute is a suitable rate of flow from the antiseptic* solution, as regulated by the screw clip. The height of the overflow tube above the symphysis pubis is adjusted according to the state of the neurogenic bladder. A height of about 2 inches is recommended for the atonic stage with gradual elevation to 10 inches or more as the hypertonic stage is reached. It is important to exclude all air in assembling the apparatus. This can be accomplished by connecting the rubber tubing to the catheter after the air bubbles have been evacuated from the tubing and while fluid is still running through the system and at the same time escaping from the bladder through the catheter. The reservoir must always contain fluid, and the end of the drainage tube must always be kept above the level of the fluid in the drainage bucket. As the bladder fills, the intravesical pressure rises until it reaches *the level of the overflow tube, at which time siphonage takes place and the* bladder empties. The cycle then starts again. To maintain proper asepsis the reservoir hsould be a bottle with a small mouth which can be plugged *with sterile gauze. (From Military Surgical Manual III, National Research Council*, W. B. Saunders.)

ing the retention caused by a hypertonic neurogenic bladder; incontinence may follow this procedure, especially in the hypotonic bladder.

PROSTATE

The prostate is a gland composed of a framework of elastic and connective tissue in which are secreting glands which empty into the posterior urethra by many ducts.

Acute Prostatitis. Acute infection of this organ is due for the most part to gonorrheal infection arising from the urethra. Infection may likewise result from nonspecific urethritis, or from trauma due to instrumentation. The infection produces pain in the perineum which is accentuated by walking. Burning and frequency of urination and occasionally terminal dysuria are usual symptoms. The systemic reaction may be quite severe, consisting of fever and its allied symptoms. Rectal examination reveals a tender and swollen prostate. On rare occasions an abscess forms with accentuation of the manifestations just mentioned.

TREATMENT. Chemotherapy, rest in bed, application of local heat, and symptomatic care represents useful therapeutic agents. There must be complete abstinence from sexual excitement. Prostatic massage is strictly contraindicated. Any abscesses which form usually rupture into the urethra but may demand drainage through the perineum.

Chronic Prostatitis. A chronic infection of the prostate may develop insidiously or be the result of an acute prostatitis. Mild pain in the perineum and burning and frequency of urination are common symptoms. A mild urethral discharge containing shreds and pus cells is usually present; such shreds and pus cells are readily found in the urine. Rectal examination will reveal a large, boggy prostate, frequently with soft, fluctuant areas. Massage of the prostate expresses the purulent "shreddy" material into the urethra from which smears may be made for the establishment of the type and severity of the infection.

Treatment of prostatitis has been improved with chemotherapy. While on chemotherapy, prostates normal except for infection should be massaged only three to five times. Persistent massage may retain infection by attendant trauma. Only hyperplastic prostates should be massaged, along with antibiotics, until they are reduced in size. They cannot be cured of infection as their drainage mechanism is abnormal, but they can be materially benefited by this treatment.

Prostatic Hypertrophy. Prostatic hypertrophy is due to an endocrine abnormality. Lower and Johnston (1931) explain the mechanism of development of the disease by the fact that the testicular tubules which utilize anterior pituitary hormone become atrophied, thereby allowing an excess amount of hormone to accumulate and act upon the prostate and seminal vesicles, resulting in their enlargement. The hypertrophy is noted particularly in the lateral lobes, but on many occasions it appears to arise in submucosal glands of the prostatic urethra. The enlargement is due to an adenomatous hypertrophy, although at times there may be considerable fibrosis scattered throughout the gland. The disease occurs only in late adult life, rarely before the age of fifty or fifty-five, when poorly understood endocrinologic changes take place in the male.

CLINICAL MANIFESTATIONS. One of the first evidences of the disease is frequency of urination, particularly at night. The patient usually has difficulty in starting the stream and when through voiding frequently has the sensation that the bladder has been incompletely emptied. The stream is weak; dribbling at the end of urination is characteristic. As the hypertrophy increases, the amount of urinary retention in the bladder increases until even the patient may be aware of the mass produced by the distended bladder. The constant presence of a distended bladder produces deleterious effects upon the kidney, consisting primarily of hydronephrosis, atrophy of the cortex, and, if infection is present, pyelonephritis or pyonephrosis. The renal impairment may be serious, regardless of whether or not infection is present, resulting at times in uremia. Any or all of the symptoms of uremia, including a clouded sensorium, delirium, weakness, headache, anorexia, vomiting, etc., may be present. The nonprotein nitrogen content of the blood will be elevated. Acute retention of the urine is commonly experienced and frequently de-

mands catheterization before relief is obtained.

Infection (cystitis) may be present early in the disease but usually does not take place until catheterization has been instituted. With infection, other symptoms, including burning and pain upon urination, become prominent. Fever and its allied symptoms are apt to be present. The infection ascends readily to the kidney and may be instrumental in the development or exacerbation of the symptoms of uremia.

Examination of the patient will usually reveal a distended bladder. The amount of retention is useful in estimating the severity of the obstruction and may be determined by measuring the amount of urine obtained by catheterization immediately after voiding (residual urine). A rectal examination rarely fails to reveal a large prostate with firm lobes, but occasionally considerable obstruction may be present due to enlargement of the median lobe with only mild increase in size of the prostate itself. Cystoscopic examination is a reliable method of confirming the diagnosis. If infection is present, pus cells will obviously be found in the urine. If much renal damage is present, albumin will likewise be present. The degree of renal impairment may be estimated by the degree of elevation of the nonprotein nitrogen content of the blood.

TREATMENT. Unless the disease is severe enough to demand operative treatment, catheterization and cystoscopic examination should be avoided. When it becomes necessary to resort to the two latter procedures, extreme care as to aseptic technic and gentleness must be utilized. Large quantities of water should be taken at all times. Urinary antiseptics as mentioned previously will be helpful in minimizing infection. It is thought by many that a distended bladder of the type encountered in prostatic hypertrophy should not be decompressed (by catheter) suddenly, i.e., not all the urine should be removed at one time, on account of damage which may be inflicted upon the kidneys by the sudden change in the pressure against which the kidney is accustomed to excrete. However, this danger has no doubt been greatly exaggerated.

Although operative removal of the prostate offers great relief to patients afflicted with this disease, urologists have learned that such procedures cannot be done without adequate preoperative treatment. In addition to proper decompression of the bladder over the course of at least two or three days, the bladder must remain empty or nearly so for several more days, perhaps best accomplished by an indwelling catheter. Observations on the nonprotein nitrogen content of the blood and the phenolsulphonphthalein excretion of the kidneys must be made at intervals to determine the patient's progress; such tests should approach normal values before operation is resorted to. Fever is likewise a manifestation which strongly contraindicates operative procedures. It is of course essential that adequate caloric intake be maintained during the preoperative period. Fluids must be forced.

Prostatectomy may be performed by the 1. suprapubic, 2. retropubic, 3. perineal, or 4. transurethral method. The suprapubic method, which is carried out by a suprapubic cystostomy, was originally the most popular. It was originally performed in two stages, with an interval of several days for bladder drainage, but in patients who are good risks or have little urinary infection, may be performed in one stage. When supported with good preoperative and postoperative care including blood transfusions, a one-stage procedure will be safe in most patients except when severe infection, elevated blood nonprotein nitrogen, or other such complications exist. Transurethral resection is performed without a skin incision by passing a resectoscope through the urethra up to the prostate. It is most adaptable in patients with small bars, contractures, or small middle lobes but is used by some urologists in nearly all cases of prostatic hypertrophy. The relatively high recurrence rate (particularly in large prostates) and the high incidence of operative and postoperative hemorrhage represent disadvantages of the method of transurethral resection. However, Emmett (29) of the Mayo Clinic reports an incidence of only 4.4 per cent (over a three-year period) requiring a second operation, and a mortality rate of only 1.2 per cent over a nine-year period. However, it should be added that not all urologists report such good results; in the hands of many, 10 to 15 per cent of patients require

rehospitalization and reoperation. Perineal as well as retropubic prostatectomy requires a high degree of surgical skill.

Carcinoma. Malignant tumors of the prostate are commonly encountered, occurring as a rule, however, at a later age than does prostatic hypertrophy. Apparently the tumor originates in the posterior lobe, which is not as a rule affected by prostatic hypertrophy. Because metastases occur early, and patients come to the physician late, the prognosis is not good.

Frequency of urination is the most common early symptom. Hematuria may be present at times. After the growth has extended throughout the gland, acute retention is frequently encountered. Occasionally the first symptoms will be severe pain in the back and pelvis caused by metastases, although the original tumor in the prostate may be proved at autopsy to be confined to only a small nodule. Diagnosis can usually be made by rectal examination by the stony hard, nodular surface, except in those instances when the initial growth remains small. Cystoscopic examination may not be of much diagnostic aid, but portions of the gland removed by the "punch" may reveal malignant tissue. Elevation of acid phosphatase is of little value diagnostically unless the level exceeds 10 King-Armstrong units.

Treatment of carcinoma of the prostate is surgical removal, provided no metastases are demonstrable and the lesion remains within the prostatic capsule. In a series of 190 patients having no evidence of metastases, Jewett (30) reports radical perineal prostatectomy resulted in a five-year survival in 50 per cent of cases. Palliation with radiotherapy may relieve pain; transurethral resection relieves obstruction. Remarkably, Huggins (31) has found that castration is followed by recession of the growth (including metastases) in 75 per cent of the cases. Estrogen (stilbestrol) is likewise effective in controlling carcinoma of the prostate, but a combination of castration and stilbestrol appears preferable. Although stilbestrol therapy and castration are effective in prolonging life (for a year or two) and relieving symptoms, they are not curative. Adrenalectomy (Huggins, 32) and injection of radioactive gold (Flocks, 33) are likewise helpful as remedial procedures though not curative.

Prostatic Calculi. Calcareous deposits occasionally develop in the dilated prostatic alveoli and may produce the symptoms of prostatitis. Removal may be accomplished by the urethroscope or by prostatectomy.

SEMINAL VESICLES

Acute vesiculitis is no doubt a frequent disease, and in most instances is secondary to gonococcal infection of the posterior urethra. It is difficult to differentiate accurately the symptoms produced by acute prostatitis, acute posterior urethritis, and those manifested by acute vesiculitis. It is agreed, however, that the pain in the latter disease is frequently localized to the region of the rectum. Rectal examination reveals tender and distended vesicles, from which may be expressed a large amount of tenacious material containing large numbers of pus cells. It is probable that this suppurative process rarely progresses to the state of abscess formation. The treatment is symptomatic, but includes complete abstinence from sexual excitement. Expression of the purulent material by gentle massage rectally, followed by urination, is probably helpful but is dangerous because of the danger of production of acute epididymitis.

Chronic vesiculitis in most instances is the result of acute vesiculitis but may develop without any evidence of preëxisting acute infection. It is apparent that in the latter instance, the streptococcus on many occasions is the etiologic factor. Symptoms are extremely variable, consisting primarily of mild pain in the perineum and along the rectum, but may be absent altogether. Ejaculation may be painful. A mild urethral discharge may be present. The disease is occasionally discovered by rectal examination performed as a part of a complete examination made, perhaps, in an effort to discover a cause for a chronic arthritis. When chronically infected, the walls may be palpated as being thickened and roughened.

Careful massage of the vesicles every five or ten days may be an effective method of treatment. Chemotherapy, including particularly the use of penicillin or sulfathiazole, should be instituted. Injection of 5 to 10 per cent argyrol into the vesicle through the vas

deferens is considered by many urologists as being effective in relieving the pain of certain types of arthritis which are due to focal infection in the seminal vesicles. Vesiculectomy may be done but advisability is doubtful.

On rare occasions the seminal vesicles may be the seat of *tuberculosis*, in which instance vesiculectomy may be indicated providing the diagnosis can be made.

URETHRA

Wounds. Injury to the urethra is not uncommon and may be produced by direct laceration or by a crushing injury such as that sustained by falling astride a fence or similar object. When there is an obvious laceration of the urethra, repair should be performed by interrupted sutures over a soft rubber catheter.

Occasionally rough catheterization results in abrasion and even a complete tear through the wall. Although strictures may result from injuries as well as infections (gonorrheal), the immediate effect of rupture or laceration of the urethra is the escape of urine into the surrounding tissues.

EXTRAVASATION OF URINE. Leakage of urine takes place readily through tears in the urethra into adjacent tissue and, because of the concomitant infection associated perhaps with gangrene, may be so dangerous as to threaten life. It is now evident that the urine acts as a vehicle to disseminate infection; urine in itself, unless the extravasation is large and continuous, is not a necrotizing agent. With the advent of the antibiotics, extravasation of urine, therefore, carries less risk because the infection can be controlled. If the injury is located in the penile urethra, the extravasation will usually be limited to the shaft of the penis; if in the deeper part of the urethra, but still in front of the triangular ligament (urogenital diaphragm), the extravasation may extend into the scrotum and anterior abdominal wall. In lacerations behind or posterior to the triangular ligament, the urine may infiltrate into the posterior perineum around the neck of the bladder and the deeper portion of the anterior abdominal wall. The tissue affected by the extravasation rapidly becomes swollen and edematous. *Tenderness* is variable but is increased in the presence of infection which is prone to develop in the involved area. The skin may become reddened; if the condition is neglected, areas of gangrene may develop. Malaise, prostration, and fever, with its accompanying manifestations, are commonly observed. The toxemia resulting from extravasation of urine is profound; death is apt to ensue unless adequate and early treatment is resorted to.

Treatment consists of immediate and numerous incisions to prevent fatal spread of infection which is so prone to develop in the tissue where extravasation has occurred. It is usually necessary to perform a suprapubic cystostomy, unless a retention catheter can be inserted into the bladder through the urethra.

Foreign Bodies in the Urethra. Foreign bodies encountered in the urethra include objects inserted by the patient or stones arising usually in the kidney or bladder. The symptoms of pain and difficulty associated with urination usually disappear after removal of the foreign body.

Urethritis (Nonspecific). Mild acute urethritis not of gonorrheal origin caused by *E. coli*, streptococcus, *Micrococcus catarrhalis*, staphylococcus, and so forth, is relatively frequent and may cause the patient (male or female) considerable worry because of the similarity of the symptoms to gonorrhea in the early stages. It may also be produced by instrumentation or chemicals injected for prophylactic reasons. Mild frequency and burning on urination, and urethral discharge are common manifestations. Most of them subside spontaneously after a few days, especially if effort is made to drink a large amount of water and to void frequently. Unless the infection is of chemical or instrumental origin, chemotherapy or the injection of 1 per cent Protargol two or three times a day for two or three days is usually effective in eradicating the infection.

Gonococcal Urethritis (Gonorrhea). Gonorrhea* is a venereal disease contracted with few exceptions only by sexual contact and is first manifested as an anterior urethritis after an incubation period of four to six days. The first symptom is a burning or stinging pain in the anterior urethra upon urination. A

* Infection in the female is discussed in Chapter 40.

slight discharge of turbid, sticky secretion is noted which becomes thick, purulent, and profuse within a few days. The meatus is reddened and swollen. Frequency of urination is always present but is not severe during the four to eight days while the infection is limited to anterior urethritis. Unless effective treatment is instituted early, posterior urethritis develops in nearly all patients and is manifested by a pronounced exacerbation of symptoms. Mild fever is commonly present. The pain experienced during urination (especially at the beginning and end) becomes severe. The patient may be awakened frequently at night by a painful erection with curvature of the shaft (chordee). After six to eight weeks the symptoms, as a rule, decrease, the discharge lessens, and convalescence is well under way, although in the untreated case a cure is not expected for many months.

A mild chronic urethritis exists for a time, but on the average no manifestations remain after five or six months except perhaps the morning drop (slight urethral discharge noted in the morning upon arising). The chronic stage of the infection usually represents a residual infection of the mucous glands along the urethra or residual infection of the periurethral tissue. On many occasions, however, the chronic stage of the disease, as manifested by mild burning and frequency of urination and slight urethral discharge, are produced by complications such as prostatitis and seminal vesiculitis. The patient is usually infectious as long as a urethral discharge is present.

The *diagnosis* of the acute stage is readily made by examination of the urethral discharge. Gram-negative intracellular and extracellular diplococci are present in large numbers. The intracellular characteristic of the organisms is extremely important diagnostically because extracellular gram-negative diplococci are normal inhabitants of the urethra and may be found in nonspecific or chemical urethritis. Urinary shreds arising from the posterior urethra are diagnostic of the chronic disease. The two glass test (see p. 1118) may be helpful in determining the presence of posterior urethritis, since there will be no turbidity of the first glass if the bladder or kidney is the seat of the infection. The confirmation of the termination of the disease may be important, particularly from the standpoint of infectivity. If the disease is still present, though symptoms are few or absent, the inflammation can usually be relighted by strenuous exercise, sexual excitement, or insertion of a urethral sound.

COMPLICATIONS. The development of prostatitis and seminal vesiculitis in association with posterior urethritis is not uncommon. In the acute stage of gonorrhea, the symptoms are increased in severity by the development of prostatitis and seminal vesiculitis but can be differentiated only with difficulty from acute posterior urethritis. An acute epididymitis may be secondary to acute posterior urethritis and seminal vesiculitis and frequently results from errors in treatment such as instrumentation, excessive treatment, or strenuous exercise. The manifestations are described elsewhere. Acute balanoposthitis (inflammation of the glans penis and prepuce) is not a common complication; it occurs usually only in the presence of phimosis. Acute arthritis (see Ch. 24) occurring six to twelve weeks after the acute onset of the urethritis is not uncommon. Periurethral and prostatic abscesses are uncommon but may add considerably to the severity of the symptoms. They may break spontaneously in to the urethra but on many occasions require incision from the exterior. Acute lymphadenitis due to a Ducrey infection is not an uncommon complication of gonorrhea but is fortunately not a serious one although it may suppurate. Swelling and tenderness of the inguinal lymph nodes may also be produced by secondary pyogenic infection. The lymphadenitis due to the gonococcus does not suppurate, but if secondary pyogenic infection is present (e.g., balanoposthitis), the lymph nodes may become acutely inflamed and fluctuant and require incision.

Urethral stricture occurs usually in the bulbomembranous urethra, results from periurethral infection, but rarely develops earlier than 18 to 24 months following the acute gonorrheal infection. It is much more common in Negroes than whites, and is frequently multiple as contrasted to the solitary strictures which follow trauma. Early manifestations consist of the appearance of slight urethral discharge, mild burning upon urination,

and decrease in size of the stream. The stricture may progress to the point that the stream is reduced to a dribble. Acute retention may develop. Because of the ulceration which frequently develops proximal to the stricture, urinary extravasation or even fistulas may develop.

Treatment is most effective if started early before serious narrowing is produced, and it *consists of dilatation of the urethra every four to six days with as large a sound as possible.* No sounds smaller than 16F or 18F should be used because of the danger of injury to the urethral wall. The size of the sound should be increased at each successive treatment until a size 28F can be passed. Any dilatation which is followed by the escape of more than a small drop of blood is harmful in that it indicates injury; thus the deposition of more scar tissue is encouraged. Unfortunately, even this amount of dilatation is not permanent and the patient should be instructed to return every six months or year for further dilatation to prevent serious contraction. If the stricture is so pronounced as not to allow the passage of a size 18F sound, it is usually wise to pass a filiform bougie which is then threaded on to a small sound and pushed into the bladder ahead of the sound. In severe cases plastic operations may be indicated and are usually successful.

TREATMENT OF GONORRHEA. Since gonorrhea can be prevented, even after exposure, the most important feature in the treatment is prophylactic. Penicillin in a dosage of 50,000 units given every four hours for six to eight doses will rarely fail to prevent the disease. Likewise, sulfathiazole given in doses of 80 to 90 grains and continued in a dose of 60 grains per day for six to eight days will prevent the disease. Prophylaxis by local means was known to be effective long before the introduction of sulfonamides; distention of the urethra for five minutes with 2 per cent Protargol up to eight hours following exposure rarely failed to prevent the disease in men. It appears logical then that local treatment combined with chemotherapy might be advisable in the prophylactic treatment. In actual practice, however, prophylactic therapy is difficult to carry out, except in the Army and Navy where compulsion is effective.

Although sulfonamides offered a great improvement over local methods in the treatment of gonorrhea, penicillin is even more effective. In over 95 per cent of cases a cure will be obtained by 80,000 units of penicillin or less, given intramuscularly every two to four hours in individual doses of about 10,000 units. Such therapy with perhaps double the dose will cure even the sulfonamide-resistant cases. In a high percentage of cases a cure can even be expected with one 300,000-unit dose of penicillin in beeswax and peanut oil given by hypodermic. Therefore, most of the foregoing statements about chronicity and complications would in reality apply only to the untreated case. It must be emphasized, however, that occasionally patients may still harbor gonococci in their urethra for some time after symptoms have disappeared, thus indicating the importance of examination of urethral smears and urine sediment. In patients resistant to penicillin, aureomycin should be tried.

EPIDIDYMIS

Acute Epididymitis. Acute infection of the *epididymis is usually gonorrheal in origin* and is a common complication of untreated gonorrhea. Since it develops only in the presence of posterior urethritis, it rarely is encountered earlier than three weeks following onset of the infection. Ordinarily, abstinence from sexual excitement, limitation of exercise, and careful supervision of treatment will prevent acute epididymitis.

The most important manifestations are tenderness and pain which develop with swelling of the epididymis and are roughly proportionate to it. A moderate amount of fever may be produced by epididymitis, regardless of its cause, but is obviously more pronounced in the acute infections. The pain and tenderness may be so severe as to be completely disabling. Rarely does the process proceed to suppuration, regardless of the cause.

Aside from penicillin, the most important feature in the *treatment* is bed rest. However, if bed rest is impossible, the application of a suspensory for the scrotum will be very helpful. Even while in bed, the pain will be greatly relieved if some sort of suspensory is applied so as to prevent dependency of the scrotum. The application of heat or cold will aid in

relief of the pain. Ordinarily the pain disappears and the swelling recedes within a few days after institution of bed rest, but if the above treatment does not afford relief, a short incision into the distended epididymis is frequently efficient in eliminating the pain, although it may not shorten the convalescence to a very great extent. The fluid obtained by such a procedure may be turbid but is rarely thick and purulent. The disease subsides rapidly under penicillin therapy if the lesion is gonorrheal in origin.

On many occasions acute epididymitis is not of gonorrheal origin. Especially is this true in elderly men who may develop the disease in the absence of a significant posterior urethritis, which ordinarily must be present before acute epididymitis develops. Vigorous instrumentation such as that associated with frequent cystoscopic examinations is not infrequently followed by acute epididymitis. Ligation of the vas deferens prevents epididymitis, and for that reason is frequently done before urethral instrumentation is performed, especially in elderly men. The nonspecific type of epididymitis is more apt to suppurate than the gonorrheal type and may require incision. Otherwise the treatment of the two types is largely the same.

Chronic Epididymitis. Acute epididymitis if untreated usually resolves into chronic infection of the organ, which may remain enlarged permanently, though produce no symptoms. Recurrent attacks are not uncommon but may be prevented to a certain extent by treatment of any existing urethritis and by having the patient wear a suspensory. The amount of pain and tenderness is extremely variable. Sterility results much less often than would be expected. Occasionally it may be necessary to excise the epididymis.

Tuberculous Epididymitis. Tuberculous infection of the epididymis is usually secondary to tuberculosis of the kidney or seminal vesicle. It begins in the globus minor, spreads to the entire organ, and may involve the testicle. The invasion is usually insidious, producing a slow, gradual enlargement without pain. There is a tendency for fluctuant areas to develop which may break down and form permanent sinuses. Because of the failure of response to conservative treatment, excision is usually indicated as soon as the diagnosis is made, providing there are no contraindications.

Spermatocele. Occasionally a collection of cloudy fluid containing spermatozoa collects about the epididymis but does not invade the testis. Such a cystic swelling is called a spermatocele. Very few symptoms are present, but the lesion may be confused with chronic epididymitis or tuberculosis of the epididymis.

TESTICLE

Undescended Testicle (Cryptorchidism). The testicles descend during the latter months of fetal life, but cryptorchidism is noted in about 15 per cent of babies at birth. The testicle may lie within the abdominal cavity but more frequently is present in the inguinal canal. Descent of the testicles will occur, however, in a large percentage of these infants within a year or two after birth. The main cause of the lack of descent usually appears to be shortness of the blood vessels of the vas; abnormalities of the inguinal canal may also exist. In view of the effect of antuitrin therapy, the primary cause appears to be hormonal imbalance.

It is essential that cryptorchidism be treated sometimes during childhood, since it has long been known that the increased temperature in the abdominal cavity over that in the scrotum is sufficient to inflict serious damage to the spermatogenic function of the testicle, which develops at puberty. Patients with bilateral cryptorchidism are usually sterile. Many observers have reported a greater incidence of malignancy in undescended testes than in descended testes, but there is not agreement on this point.

Treatment. During recent years the gonadotropic hormone of pregnancy urine (antuitrin S) has been used with varying results in the treatment of cryptorchidism, but on account of frequent recurrence and damage to the testicle, it is being abandoned by many physicians. Operative correction, preferably between the ages of eight and twelve years, is again becoming the procedure of choice. A hernia is usually present along with the undescended testicle and should be repaired at the same time.

Operation consists of opening the canal, finding the testicle, dissecting away the short

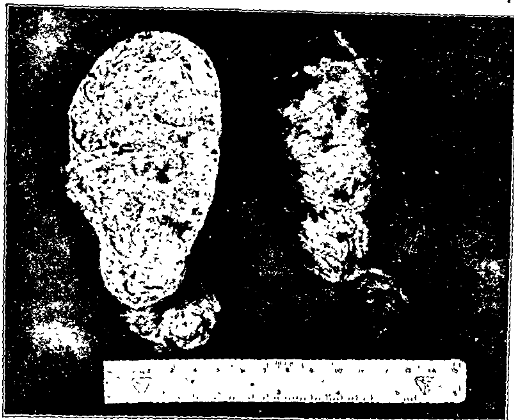


Fig. 16. Teratoma of the testicle in a man, aged 28. Enlargement of the testicle was first noted four months previously. The Aschheim-Zondek test was positive; two weeks after operative removal of the tumor it was negative.

fibrous tissue strands connecting the tortuous vessels, freeing the vas, and anchoring the testicle to the fundus of the scrotum (Bevan) or to the subcutaneous tissue of the thigh (Torek). The latter procedure requires a minor operation several weeks or months later to separate the attachment to the thigh.

Torsion of the Spermatic Cord. Because of a weakened gubernaculum associated with maldescent, the testis may be suddenly pulled upward by the cremaster muscle in such a manner as to allow twisting of the cord. This rarely occurs in children. The blood supply may be completely strangulated, in which case gangrene of the testis occurs, terminating in an abscess or atrophy of the testis or both. *The pain associated with torsion of the cord* is intense. Nausea, vomiting, and mild shock may be present. *Unless reduction can be attained within an hour after development of the torsion, operation (orchidectomy) is advisable.*

Miscellaneous Diseases of the Testis. As a tertiary manifestation, *syphilis* may affect the testis either as an *interstitial orchitis* or as a *gummatous degeneration. The swelling* is insidious and associated with no pain or inflammatory signs. Antiluetic treatment produces *a retrogression* of the swelling.

There are a few diseases, among which mumps is the most important, which may be associated with *orchitis.* During the acute process the testis may be swollen and tender, but atrophy later develops. *Tuberculosis of the testis* may be encountered in association with tuberculous epididymitis, but is a rare lesion; orchidectomy will usually be strongly indicated.

Tumors of the Testis. With the exception of a few benign tumors, such as fibroma, most tumors of the testis are *malignant. They may be divided into two major groups:* 1. teratomas (Fig. 16) and 2. seminomas. *Teratomas arise from the sex cells but contain many* different types of tissue, including muscle, cartilage, and fat. They occur in young adults, *are very malignant, grow rapidly, and metastasize* to the lumbar chain of lymph nodes as well as to the nodes in the retroperitoneal *portion of the upper* abdomen. Reference has

already been made to the relation of malignant tumors to cryptorchidism. It should be mentioned that tumors of the testicle frequently develop insidiously, the patient being entirely unaware of their presence. Even if he consults a physician, the enlargement may be passed up. In a few instances a relatively small tumor may metastasize and produce manifestations of epigastric enlargement before the patient is aware that there is anything wrong with his testicle. In teratomas, the amount of *chorionic* hormones in the urine is increased, whereas in seminomas the amount of *hypophyseal* hormones is increased; the former gives a positive Aschheim-Zondek test, but the latter does not.

TREATMENT. As soon as the diagnosis is made, orchidectomy should be performed unless metastases are obvious and growing so rapidly as to threaten life within a very short time. Dissection of lymph nodes at the time of the orchidectomy does not appear to increase the chances of a cure. Radiotherapy is effective in seminomas but only occasionally so in teratomas. Ultimate results from the standpoint of five-year cures are very poor in teratomas and fair in seminomas.

PENIS

Phimosis. Frequently, the orifice of the prepuce is congenitally too small to allow retraction behind the glans (phimosis). This allows accumulation of smegma which may be the source of considerable irritation. This irritation may at times be associated with considerable infection of the glans and prepuce (balanoposthitis). Adhesions between the glans and prepuce are frequently present. If the preputial orifice is large enough to allow retraction, these adhesions may be separated readily in children without resorting to operative procedures.

Circumcision is strongly indicated in all instances when there is an actual phimosis and is advisable when the prepuce is redundant. It may be performed at any age. Local or general anesthesia may be used, depending upon the age of the patient. A dorsal slit is made backward to within 0.5 cm. of the sulcus. Excision of the prepuce is carried forward on each side with a scissors until the incisions meet in front of the frenum on the ventral side. A generous amount of skin must be left on the ventral side near the frenum so as to prevent deformity of the penis during erection. All bleeding points must be carefully ligated. The cut edges are then approximated with interrupted sutures of 000 catgut.

Paraphimosis. When the prepuce is tight and becomes retracted, it is occasionally difficult or impossible to reduce it because of the edema which rapidly develops. The prepuce distal to the line of constriction becomes very edematous. The glans may be cyanotic and painful; if the constriction is complete enough to block all circulation, gangrene will develop. Reduction should be attempted, but not until the edema of the glans and prepuce distal to the constriction has been squeezed out by digital compression. If this can be accomplished, reduction may be possible. However, if reduction is impossible, and necrosis of tissue seems imminent, it is advisable to cut across the constricted prepuce in a longitudinal direction on the dorsal surface and treat the patient by bed rest and local irrigation until the edema subsides. After the edema and inflammation subside, circumcision may be performed in a routine manner.

Carcinoma of the Penis. Rarely indeed is carcinoma of the penis encountered in a patient who has been circumcised, suggesting that in this instance irritation is an important factor in the development of the tumor which usually appears on the unexposed surface of the prepuce. The tumor is of the squamous cell type and metastasizes slowly to the inguinal lymph nodes (Fig. 17).

The type of treatment required depends upon the size of the carinoma. If small, it may be excised locally, and after a dissection of the inguinal lymph nodes has been performed, x-ray therapy should be given over the penis and groins. If the tumor is large, amputation is advisable. Since these tumors are of the squamous cell type, they usually recede favorably after x-ray therapy.

Congenital Anomalies. Very few of the anomalies of the penis are common unless phimosis, as already discussed, is considered to be congenital. An abnormally small urethral meatus is, however, fairly frequent.

HYPOSPADIAS. This lesion, consisting of the location of the urethral meatus on the *ventral* surface of the penis, proximal to its normal



Fig. 17. Squamous cell carcinoma of the penis. A, appearance of the lesion six month after onset; B, low power photomicrograph from a section of the excised specimen; note that the hyperplastic epithelial growth is invading the subcutaneous tissue.

position, is in reality just as much an anomaly of the urethra as the penis. There are three types: 1. balanic, in which the meatus is located at the junction of the glans and shaft; 2. penile, in which the meatus is located at the penile-scrotal angle; and 3. perineal, in which the meatus is located just in front of the triangular ligament. A downward and backward curve of the urethra, noted particularly upon erection (chordee), is usually present because of an atrophy or absence of the corpus spongiosum and the presence of a fibrous band along the ventral surface of the shaft.

Treatment is operative and is usually confined to the penile type because treatment is less satisfactory in the other types.

Innumerable operations have been devised to correct the anomaly. The urethra is constructed by skin grafts of various types taken from the thigh, prepuce, or scrotum. Scar tissue on the ventral surface must be excised. Furthermore, to prevent deformity upon erection, it is necessary to construct a long urethra.

Epispadias. This anomaly, consisting of the location of the urethral orifice on the dorsal surface of the penis, is less common than hypospadias. The defect which represents a cleft, may extend through the entire length of the shaft and even be associated with exstrophy of the bladder.

Herpes Progenitalis. Single or grouped blisters may arise on the glans penis or skin and a few days after onset the blisters may rupture, after which infection frequently occurs. This lesion is seen frequently and is often ushered in with considerable pain which disappears as soon as the vesicles appear. Treatment consists of cleanliness and dusting powders.

MISCELLANEOUS LESIONS

Hydrocele. There are different varieties of hydrocele (Figs. 18, 19), most of which are congenital in origin. A few appear to be



Fig. 18



Fig. 19

Fig. 18. Hydrocele in a boy, aged five. The swelling was first noted two years previously.

Fig. 19. Hydrocele in a man, aged 55. The swelling was first noted six months previously. All of the fluid was removed by aspiration three weeks previously, but, as is usually the case, reaccumulated rapidly.

caused by infections or by operative procedures. The vaginal type of hydrocele (fluid in the tunica vaginalis) is said by many observers to be the most common, but the fact that most hydroceles extend so far upward along the cord suggests that patency of the distal cord of the funicular process exists at least to a slight degree in most instances.

There is usually a history of a slowly growing mass in the scrotum which, with the exception of the congenital hydrocele, is irreducible. They are pear or oval shaped and may attain an enormous size, containing several hundred milliliters of fluid. The mass is dull to percussion. No impulse is noted over the mass upon coughing except when a hernia is also present and projects downward against the apex of the hydrocele. The mass transmits light except in the rare instances when a chylous hydrocele (containing shimmering cholesterol crystals) is present. The fluid contained in the sac is usually clear and straw colored, but may be colorless and opalescent.

Treatment. The mass may be reduced readily by aspiration, but fluid always reforms, except in infants when multiple aspiration may be curative. Injection of sclerosing substances may at times be successful. There are two types of operative procedures: 1. The bottle operation consists of making a small incision in the apex of the sac and inverting the testicle through the hole in the sac. This is a simple procedure quickly done, but is occasionally followed by a tender mass which may have to be excised later. 2. Excision of the hydrocele sac along the margin of its attachment with the testis and cord probably results in a greater percentage of cures than other procedures. On account of the delayed tendency for the tiny vessels on the cut surface of the sac to stop bleeding, it is essential that a running suture of fine catgut be taken along the cut edge to prevent postoperative hemorrhage, which is a serious complication from the standpoint of obliteration of the blood supply to the testis with resultant atrophy.

Varicocele. Dilatation of the spermatic veins is a common anomaly and is probably of congenital origin. It is usually located on the left side because the left spermatic vein has no valves and empties into the vena cava at right angles. Standing for long periods of time and strenuous exercise are probably secondary etiologic factors. The dilated veins are tortuous and rarely associated with tenderness or pain. Occasionally mild discomfort in the scrotum is complained of, but this is usually relieved satisfactorily if the scrotum is supported with a suspensory. Excision



Fig. 17. Squamous cell carcinoma of the penis. A, appearance of the lesion six month after onset; B, low power photomicrograph from a section of the excised specimen; note that the hyperplastic epithelial growth is invading the subcutaneous tissue.

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MISCELLANEOUS LESIONS

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MILITARY SURGERY

Frank B. Berry

History reveals that with each successive war of any magnitude the problems of military care become more complex because of the increasing number of people involved; the increasing variety and lethality of the weapons and the counter measures used against them; the broader scope and greater mobility of warfare with resulting diversity of geography and climate; and, finally, the increasing medical knowledge, its tools, and its elaborate equipment. In World War II the large numbers of civilian casualties from the bombing of cities brought many new problems which, although incident to war, are not strictly within the field of military surgery; hence, a discussion of them and a plan for their care will be omitted.

As we face the present we are confronted by a new and terrifying force: the thermonuclear (fission) weapons, bombs or guided missiles, fired from the air, land, ships, or submarines. With rocket propulsion these already carry for hundreds of miles with a considerable degree of accuracy. Therefore, we must consider military medicine and surgery under two widely different situations:

1. That concerned with the conventional type of warfare, which will be considered first.
2. That concerned with a major catastrophe or disaster occurring from a sneak attack, delivered simultaneously on many targets with thermonuclear bombs from the air and guided missiles from submarines or more distance bases. This is truly "survival" medicine and surgery and will form the subject of the second part of the present chapter.

Military Surgery, per se, may be defined as the surgical care of the personnel of the Armed Forces, and of others entrusted to their care, in time of war. It is a part of a closely coordinated and highly integrated organization which may be called upon to operate efficiently and simultaneously, under vastly different conditions, in all parts of the world. Such an organization must be flexible and mobile; it must establish long lines of evacuation for its sick, wounded, and disabled; and it must so phase the necessary procedures that the lines of evacuation are always kept open with minimal strain upon them. This requires a high degree of professional judgment so that lightly wounded men who are, or may soon again be, of use in a given combat zone may be held there, while those who are seriously ill or wounded may be evacuated promptly. This prevents confusion in that it not only keeps open the lines of evacuation, but it also prevents unnecessary crowding and muddle in the rear areas and thus lessens the load in replacement centers and in the flow of personnel to the front.

Military surgery has to do largely with a group of comparable individuals, for the most part young, healthy males, who are the recipients of wounds and trauma produced by similar types of weapons, objects, and vehicles. Because of these causative agents similar patterns of injury often appear: "mine" or "deck feet," "trench foot," "desert sore," "frostbite"; identical patterns in flash burns; characteristic wounds caused by high explosives and high velocity missiles; and burns and radiation injury from the use of nuclear weapons. Wounds of major arteries and joints are somewhat analogous and are amenable to standardized forms of treatment. Finally,

of the varicose veins will rarely fail to relieve the symptoms but is not often indicated.

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prompt the surgery may be, truly lethal wounds will always be fatal because of their very nature. Hence, the earlier the wounded arrive in the hospitals, the greater will be the hospital death rate, no matter what is done, but there will be a corresponding lowering of the killed in action (KIA) rate and the diminution of the KIA:WIA (wounded in action) ratio. This is a fact not commonly recognized, and it is erroneously thought by some that the farther forward surgery is performed, the greater will be the percentage saved. There is an optimum point for the most forward surgical installation beyond which the law of diminishing returns operates with increasing rapidity, and at the same time such hospitals are exposed to increasing risk of capture, destruction, or damage, plus a progressive inability to function properly. The majority, probably over 95 per cent, of those listed as "killed in action" die from head wounds, by being literally blown to pieces by exploding shells or bombs, or as a result of hemorrhage from extensive wounds of the heart or great vessels. There is no salvage in the first two groups, and that in the third is extremely small but, barring such wounds as these, the wounded usually live, including even a large number with wounds of the heart and great vessels.

THE NATURE OF MILITARY WOUNDS

Inasmuch as the military surgeon must, perforce, be primarily concerned with the wounded soldier, he should be cognizant of the common causative agents and the nature of the wounds they produce. In the production of weapons and ammunition careful studies and tests are made so that the effects produced within given areas and under given conditions are known with astonishing accuracy, i.e., the number, size, distribution, and damaging effect of fragments of shell casing that may be expected from the burst of each shell or bomb, or the pattern of damage caused by a land mine or booby trap. Less accurate studies have been made as to the relationship between causative agents and wounds. According to such data as are available, however, approximately 70 per cent of the wounds in World War II in the Army were caused by artillery and mortar fire, but the mortality from bullets was slightly greater. The direct aim possible with small arms probably accounts for this. In World War I explosive missiles were responsible for 50 to 80 per cent of all wounds, the rate being highest when battle conditions were most stabilized. A parallel condition existed in the European Theater in World War II in that after the German resistance was broken and the tactics were those of pursuit, the proportion of bullet wounds rose.

Causative Agents. Although weapons are employed in various manners in different tactical situations, the injuries inflicted are the same and fall under the headings of explosives, bullets, secondary missiles, violent displacement, exposure to elements, heat and fire, and radiation of varying intensity. Bayonet wounds are rare, and neither chemical nor biological warfare was employed in World War II.

TABLE 1. Causative Agents of Wounds
An Army (U.S.), World War II
September 1944—May 1945

BULLETS		
Unspecified	4,790	
Rifle	5,882	
Machine Gun	1,774	
Total	12,446 =	24.8%
HIGH EXPLOSIVES		
Unspecified	28,130	
Shell (artillery)	5,389	
Mine	1,868	
Booby Trap	81	
Blast Concussion	1,711	
Grenade	22	
Bomb	557	
Total	37,758 =	75.2%
Other	0	
Total Wounds	50,204 =	100.0%

1. The explosives: artillery and mortar shells, bombs, grenades, rockets, land mines, booby traps, anti-aircraft flak
2. Bullets: rifle, machine gun, small arms
3. Fire: flame-throwers, cordite, incendiary bombs, flash (gasoline), phosphorus
4. Bayonets
5. Secondary missiles: masonry, armor, dirt, etc.
6. Crashes: aircraft, glider, vehicle
7. Exposure to elements: frostbite, trench foot
8. Thermonuclear weapons
9. Chemical warfare: gases
10. Biological warfare

common patterns in disease and infection also appear: malaria, amebic dysentery, neuropsychiatric problems, and wound infections due to the clostridia or *C. diphtheriae*.

In order to provide the best and safest treatment for illness and trauma, occurring as they do in war in such a steady and at times almost overwhelming flow, certain measures of standardization are essential. It is not at all the desire to bar individual initiative nor to restrict the ability and skill of the more expert, but rather to stimulate them and direct their effort into the most effective channels and at the same time to assist and instruct the less experienced. Letters and directives are issued, therefore, as necessary sources of advice and information and for the purpose of simplifying, expediting, and improving the surgical care of the wounded, so that those working in the field may be kept informed at all times of new developments, changes in and evaluation of the procedures employed, and their phasing.

The functions of every medical installation from the company aid post to the hospitals in the Zone of Interior, together with the duties of the surgeons in them, should be carefully delineated so that the mission of each is clear. This done, then personnel of proper skill and professional qualifications must be so apportioned among these units as best to accomplish these different missions. Each procedure must be timed in relation to the whole problem involved; otherwise, even though performed with the greatest expertness, it may be entirely wasted if undertaken at the wrong time or in the wrong place. Thus different types of hospitals have been provided, staffed, and equipped for surgery of varying urgency, magnitude, and duration of convalescence. The Field or Mobile Army Surgical Hospital unit (MASH)* is small, highly mobile, and well equipped to care for a relatively few cases of the most urgent surgery by supplementing its intrinsic staff temporarily with expert surgical teams from auxiliary surgical groups. But to enlarge it so as to care for patients who can safely tolerate further travel or to extend its scope of surgery destroys its mobility and clogs its beds. As the MASH unit takes care of the Priority I surgery, so the Evacuation Hospital takes care of the next group, which might be termed Priority II. The primary function of both of these hospitals concerns *Initial* surgery. The MASH unit concerns itself only with resuscitation and immediate surgery necessary to preserve life and limb and correct grave physiological disturbances. Depending upon the tactical situation the Evacuation Hospitals will perform necessary surgery upon such patients as will probably return to duty within a week or ten days. The surgeons will perform careful débridements and reduction of fractures and apply plaster casts for transportation to the rear for the fracture group and those with extensive débridements; and they will perform the initial surgery, which may be definitive, for wounds of the abdomen, chest, and central nervous system.

* Has now been redesignated, similar to platoons of a Field Hospital.

CONVENTIONAL MILITARY SURGERY

Battlefield care forward of the most advanced battalion aid station is itself of first importance in saving the lives of a small group of men, such as those who perhaps might die of hemorrhage from a large vessel of an extremity or asphyxiation of obstructed airways, both of which can be corrected on the battlefield by the aid man or at the advance aid station by trained personnel. The importance of this small zone is not generally realized.

The closer a hospital is to the front lines, the higher will be its case mortality rate. This is because the farther forward it is, the greater the number of wounded it will receive who would ordinarily die on the battlefield. As a rule only a small proportion of the wounded are operated upon within six hours of their injury. This is due to the time required first, to remove them from the field, second, to evacuate them to the hospital, and third, to prepare them for operation. Some of the surgeons working in the field hospitals in World War II, because they had always been taught that six hours was the "golden period" for wound surgery, expressed concern over the fact that the mortality in the zero to six hour group was as high as it was in those receiving surgery in from six to twelve hours, or higher. Here a distinction must be recognized between the surgery of *wounds* and of *lethal wounds;* no matter how perfect, skillful, and

GENERAL ORGANIZATION FOR TREATMENT

Priorities in Treatment. Under ordinary civilian conditions, there is little or no priority in the treatment of the injured inasmuch as there are usually sufficient time and facilities to care for all of them. In combat or during extraordinary civilian catastrophes, the number of injured may be so great as to require triage, or sorting, of the casualties with a definite and prearranged system of priorities of treatment. Proper triage demands experienced professional ability and full understanding of the existing tactical situation; hence, a triage team should consist of surgeons of mature judgment and capable of prompt decision. Hard and fast rules cannot be laid down, and decisions must obviously be governed by such considerations as available personnel, amount of supplies, transportation facilities, and the exigencies of the military situation, which in general supersede other considerations since they are more directly connected with the immediate aims of warfare and the protection of the healthy and intact fighting forces.

In the United States Army, triage of casualties occurs in the Combat Zone in five medical installations in the chain of medical evacuation: 1. Battalion Aid Station; 2. Collecting Station; 3. Clearing Station; 4. Mobile Army Surgical Hospital (MASH), or platoon of the field (surgical hospital); 5. Evacuation hospital. Depending upon the given situation, these may leap-frog each other rapidly, extend laterally, or be temporarily located with relatively long intervening distances. The Collecting Station may be bypassed entirely, and at times the Mobile Army Surgical Hospital may be located in close proximity to an evacuation hospital, or with temporary expansion may indeed serve as one: hence the flexibility of this type of evacuation. The important features to be emphasized are that it is *flexible* and also provides a functional three-point system: a first aid station, triage center (the clearing station) with a hospital for the nontransportable severely wounded very close by, and a larger hospital within a relatively short distance to the rear or lateral.

Emergency Medical Treatment. First aid treatment is administered by the soldier himself or by a fellow soldier, who is usually one of the Company Aid men. The care of the wounded begins *here* on the field. The Aid men arrest external hemorrhage, apply snug sterile dressings, put on temporary splints, administer morphine for pain, and arrange for the transport of the patients to the Battalion Aid Station either by litter, by small or improvised field ambulances if possible, or with assistance to the wounded who can walk. In wounds of the extremities, the tourniquet may be life saving when applied. Its purpose is to *stop* bleeding. When hemorrhage cannot be controlled by pressure and a firm bandage, a tourniquet is applied proximal to the wound and drawn tight until all bleeding has ceased. Only after this purpose has been attained is the dressing applied and the limb immobilized. The trained enlisted personnel of the Armed Forces' Medical Services are efficient in their knowledge and use of first aid measures. "The U.S. Army Medical Department soldiers, the 'medics,' accompany all of our troops into battle and accord our wounded first aid care and probably more rapid evacuation and finer individual care than are accorded the wounded of any other army." (3).

The Battalion Aid Station. Here the medical officer applies or rearranges dressings and splints when necessary and removes tourniquets if he considers them unnecessary. If morphine has not already been given, this may be done now if deemed necessary by the medical officer. A booster dose of tetanus toxoid is administered as is an initial dose of antibiotics. It is here that the first real steps in resuscitation are taken by assuring arrest of hemorrhage, immobilization and traction of fractures of the long bones, airtight dressings for chest wounds or relief of tension pneumothorax, a free airway, and administration of plasma (expander), which may be continued during transport. Occasionally whole blood may be provided in a Battalion Aid Station when this is possible and conditions warrant. Often this is impossible because of difficulty in supply and refrigeration. The prime objective is to keep the aid station clear and patients at a minimum so that the patient may reach a hospital where more effective resuscitation is possible and initial

Missiles of low velocity do not penetrate deeply and exert their effects mainly by contusion and laceration, and the initial velocity of shell, bomb, grenade and mine fragments, though very great at first, decreases rapidly. Secondary missiles are earth, stones, armor, masonry, bone, etc., liberated and dispersed by the primary explosion. Large or small missiles of very high velocity from shells, mines, grenades, or bombs,

in the first portion of their flight, and rifle bullets within the first mile of their flight, produce "explosive" wounds, with the wound of exit larger than the wound of entrance. Shape and velocity remaining the same, doubling the weight of the missile doubles its wounding power. Shape and weight remaining the same, doubling the velocity quadruples its wounding power, since it quadruples its energy. When weight and velocity remain the same, increase in sectional area either regularly or irregularly, as in a bullet with flattened point or one with the deformity of a split jacket, produces additional wounding capacity, and especially its "shock" effect, which cannot be stated mathematically since it will vary so greatly, with the character of the tissue affected (1).

With the rapid decay in the velocity of shell fragments, much of their damage is due to the tissue damage caused by their size and weight, the dirt and clothing carried in by them or by secondary missiles set in motion by them.

"The wounding effects of a bullet depend on (*a*) the amount of energy it transmits to the tissues, (*b*) the velocity of the transmission, (*c*) the direction of the transmitted energy, and (*d*) the density of the tissues" (1). High velocity bullets travel at over 2,000 feet a second and rotate on their long axes at about 3,000 revolutions a second. The muzzle energy is about 2,400 foot pounds and the rotatory energy about 12 foot pounds. If a missile does not emerge from the body, its entire force is absorbed by the body. If it emerges, obviously all of its energy has not been expended. When a high speed missile, even a smooth pointed rifle bullet, enters the body, it may cause terrific damage at some distance from its line of passage because the energy of the bullet is transmitted all along its path at oblique angles. Particles of clothing or dirt are scattered in like manner through the path along these lines of force and the tissues are blown apart momentarily as though by an internal explosion. In homogeneous tissues all particles move together in a wave-like manner, the motion varying with the density of the tissue involved. When varying densities are encountered, however, as when a bone is shattered, irregular stresses are developed and the bone fragments become so many secondary missiles.

Three zones have been described in wounds caused by high velocity missiles: first, the innermost zone, the wound channel, filled with necrotic tissue, old blood, and debris; second, the zone of direct traumatic destruction with cauterization of tissue, which varies in width and forms an excellent culture medium for bacteria; and third, an outer zone of tissue of greatly reduced vitality, likewise suitable for bacterial growth (2). If this concept of the high velocity missile wound is understood, the objective of adequate careful débridement will be better comprehended.

Blast. The effects of blast were studied after World War I and again early in World War II. Injuries from bomb blasts are sustained from: 1. the fragments of the bomb itself, 2. secondary missiles such as flying debris and falling masonry, 3. falling or being thrown, and 4. the concussion of the blast wave. The blast wave consists of a shell of air traveling initially at about 3,000 feet per second in all directions but falling away rapidly. The injury is occasioned by the impact of the wave on the body, like a sudden blow. The ear drums may be injured, but the damage to the lungs is the chief effect. This consists of subpleural and intrapulmonary hemorrhages with possible rupture of the alveolar walls. In the abdomen, there are sometimes subserosal hemorrhages in the intestines or even rupture at times. In the central nervous system, it is not entirely clear how much of the injury is from the blast itself or how much may be due to concussion subsequent to sudden displacement of the head by the blast.

Explosions of mines or depth charges in water produce a single high pressure wave. Both lungs and intestines are affected, but the peritoneal injury predominates and ruptures of the intestines, especially the colon, are frequent.

thighs, extremity wounds with severe vascular injuries or evidence of anaerobic infection; 3. major traumatic amputations and compound fractures of the long bones with extensive soft part damage. In order to preserve maximum mobility and assure the best care for their patients, these small hospital units of 50-60 beds should hold as few patients as possible for actual operative surgery. After observation, adequate resuscitation, arrest of hemorrhage, and other necessary procedures, further triage can be made of this group of casualties so that about 40 per cent may be evacuated to the Evacuation Hospitals for definitive treatment or for further care and operation before transfer to a General Hospital.

Special Hospitals. In order to conserve as many men as possible who may be potentially able to return to duty within 48 hours, holding stations or "platoons" for special types of patients may be established well forward, usually in the vicinity of Clearing Stations or only slightly to the rear. As a rule, in combat, there are two of these: 1. for venereal disease, and 2. for acute neuropsychiatric disorders due to battle fatigue, where patients may be rested and observed for 48 hours, after which many are frequently able to return to their units. These patients live under full field conditions, require minimum treatment for this initial period, and lighten the load in the hospitals further to the rear where beds are so much in demand. With modern therapy the patient with venereal disease does not need any prolonged hospitalization and is soon fit for duty again. The soldier with exhaustion or battle fatigue may respond rapidly to rest and sedation, and it has been found in all wars that it is far better to keep such patients near the front because once they are evacuated to the rear, it becomes increasingly difficult to return them to active duty.

The Evacuation Hospital. All patients not requiring first priority surgery in the MASH units (and all medical and venereal cases) are sent directly to the Evacuation or Special Hospitals from the Clearing Station, and in addition the Evacuation Hospitals receive the small groups of patients from the MASH units, as mentioned above. Here again all patients are triaged on admission and labeled according to priority. This triage is usually performed in the admission tent by one or more senior surgeons, and priority is established for resuscitation and place on the operative schedule. Either different colored tags are used, or different wards are provided for first and second priority cases. Sometimes, if the load of admissions is unusually heavy and transport facilities are good, still another group of patients is selected for immediate evacuation. This group consists of those, both ill and wounded, for whom it is believed that initial definitive treatment may safely be deferred, and those who can stand transport and who will receive earlier attention at another hospital than they will if they have to await their turn where they are, because of the existing backlog of untreated patients.

In the foregoing paragraphs, an outline has been given of the various medical installations through which a wounded soldier passes on his way to a general hospital in the Communication Zone. Criticisms at times have been made that this system is too complicated, necessitates too much handling of the patient, and encourages delay. But the treatment of badly wounded soldiers, not singly but in large numbers, is itself complex, and a well planned organization is required to accomplish it so that: 1. the best possible care is provided; 2. this care ensures safety and is within the capabilities of the available medical personnel at all points; 3. the lines of evacuation are always kept open; and 4. facilities are provided at the most forward point possible to which nontransportable patients may be carried without delay to receive expert surgical care. At this place, there must be water, heat, light, shelter, and space to hold patients so that sufficient facilities may be provided for the care of this group. It is not practicable to establish such an installation farther forward than the Clearing Station. Even here, it is sometimes forward of the Division artillery. But the small unit, the MASH operating close beside the Clearing Station, fulfills the requirements of the three-point system described by Jolly (5): triage point, an adjacent small hospital for the nontransportable, the larger hospital farther back from the others, which thus makes possible selective and highly expert surgical care with minimum delay. Each unit along the way from

surgery and other treatment may be instituted without delay.

The emergency medical tag (EMT) should be started if this has not already been done by the Aid man, and the following information is of the utmost importance, requires little time, and should be stated on the tag as fully as possible. Quite apart from the name, serial number, and unit, *how, when,* and *where* wounded should be stated and any therapy noted. "How" is the type of missile if known; "when," the day and hour; "where" means primarily the geographical area where the man was when wounded, although of course the parts of the body involved should also be stated. If tourniquet is used, it should be clearly stated. Administration of morphine, tetanus toxoid, antibiotics, initial dressing, and intravenous therapy are of great importance and should be so recorded. Any special warning as to urgency of evacuation, treatment, or surgery is also noted.

From the Battalion Aid Station the wounded are evacuated to the Collecting or Clearing Station by ambulance, jeep, helicopter, or even by litter carry. The responsibility of evacuation always rests with the rear unit; thus, the responsibility for evacuation of the Battalion Aid Station rests with the Regimental Medical Company or the Division Medical Battalion, using ambulances or helicopters. Here the responsibility of evacuation rests entirely with the Division. The Army is responsible for evacuation of the rearmost Division installations such as the Clearing Station or the Mobile Army Surgical Hospital. The Communication Zone in turn is responsible for evacuating the Army installations, and finally, evacuation from the Communication Zone is furnished by the Zone of Interior.

The Clearing Station. The Battalion Aid, Collecting and Clearing Stations service the Division. Casualties passing to the rear of this zone are cared for by the Army. The Division is an extremely mobile unit; hence, its medical installations are similarly organized so that only those patients with trivial wounds or minor illness can be retained in them.

Clearing is the process of disposing of the casualties of a division or comparable unit. It consists of sorting all casualties of the unit, returning to duty such as are immediately fit for full duty, and transferring all other, except the dead, who are the responsibility of the Graves Registration Unit, to a medical unit of a higher echelon [Field Army. Ed.]. It is not to be confused with hospitalization.

In other than combat situations, if a clearing unit be organized and equipped for the purpose, it may undertake limited care and treatment of such sick and injured as will be fit for duty within a short time (4).

To what extent a Clearing Station can perform this second function in time of war depends upon its location and the tactical situation. In actual combat its function is largely that of triage and urgent resuscitation, and it holds only the slightly ill and those with very minor wounds. Whole blood is available in the Clearing Station.

Of the wounded and injured to be evacuated further a certain proportion will be nontransportable. A "nontransportable" casualty is a patient who cannot be evacuated further without real danger to life. Such a patient is transferred immediately to the Mobile Army Surgical Hospital, which should be, as a rule, within "hand-carry" distance from the Clearing Station. All other wounded are sent on back to the Evacuation Hospital except as noted above.

Evacuation by helicopter commonly begins at the Clearing Station, although in favorable instances helicopters may be sent forward to the Battalion Aid Station or even onto the field itself; this means of evacuation of the wounded is rapid and the most comfortable.

Mobile Army Surgical Hospital. The MASH units supporting the Clearing Stations are small, complete surgical hospitals of fifty beds each equipped to care for nontransportable casualties. These are: 1. those suffering from grave, life-endangering physiological disturbances such as hemorrhage, severe shock, cardiorespiratory imbalance from wounds of the heart or pericardium or large sucking wounds of the chest, intracranial pressure, and certain maxillofacial or neck wounds in which there is obstruction to respiration; 2. a group of impending fulminating infections including all thoraco-abdominal and abdominal wounds or wounds in other areas that may have penetrated the abdomen, such as wounds of the buttocks and upper

scalpel, but are equally dangerous to the patient if used without expert precision. One of the major responsibilities of the military surgeon is to make full use of these and similar measures and at the same time to avoid the dangers that may attend their usage.

a. The ever present necessity for evacuation of the wounded to the rear is in fundamental conflict with ideal surgical management of the individual patient. To minimize this conflict, *close coordination between the functions of administration and professional services is required.* It is the responsibility of the medical officer charged with the surgical management of the patient to place technical procedures properly, both in time and in space, with due regard to the tactical situation on the one hand and to the welfare of the patient on the other. Unless the surgeon visualizes his position and the function of his hospital in relation to other surgeons and other hospitals, he may become confused in the mission he is to perform. Although some needed operation may be performed correctly, the military effort may be impeded and unforeseen harm done to the patient if the operation is done at the wrong time or in the wrong place.

b. *It is the responsibility of administrative officers* charged with the establishment of evacuation and hospitalization policies to adapt the schedules of movement of patients to the maintenance of highest standards of surgical treatment. Priority of movement must be accorded to patients with certain types of injuries just as the duration of hospitalization in a given zone must be differentially adjusted to the urgent surgical needs of the patients. The term "nontransportable" as relating to the unfitness of battle casualties for interhospital transfer must, when military necessity permits, be extended beyond actual danger to life by a consideration of the likelihood of deformity, ultimate disability, and delay of recovery when these hazards exist (6).

Timing of Surgery. In war the timing of surgical procedures is of primary importance. It must be realized that the wounded soldier may pass through many medical installations before his final disposition—frequently as many as four to eight in the theater of operations. Treatment must be definitely planned in advance, therefore, and a clear conception of the type indicated in the various echelons must always be kept in mind. Only by such proper staging of surgery and the keeping of careful records can the best care be provided. There is nothing hit or miss, but the efforts of an expert surgeon may be entirely wasted if they are applied improperly as to time and place. Churchill has divided war surgery into the initial, the reparative, and the reconstructive phase. The first two belong in a theater of operations, the last belongs to the Zone of Interior (7).

Initial surgery is such surgery as is necessary to save life and limb, to correct physiological disturbances, and to prevent and treat infection. It includes resuscitation and the treatment of surgical shock, which of itself accomplishes two purposes: 1. it makes the patient transportable; and 2. it makes surgical intervention possible. The initial surgery itself is not intended to be definitive in any sense of the word, although at times it may be. Included in both are the control of hemorrhage; establishment of a good airway; temporary correction of cardiorespiratory disturbances with tracheostomy when necessary; surgery of the abdomen; clean débridement of wounds and of penetrating wounds of the joints with installation of antimicrobial and closure of the joint capsule; completion of traumatic amputations; transportation immobilization of fractures. When circular plaster is used, both it and any encircling bandages must always be cut before the patient is evacuated. When the spinal cord is involved and there is paralysis of the bladder, a suprapubic cystostomy should be performed. This is safer and less troublesome than the insertion of an indwelling catheter. Tracheostomy may be lifesaving but should not be undertaken lightly as it must be realized that such a patient may require considerable care during the first few hours following this operation.

Records. The emergency medical tag (EMT) should be carefully noted and corrected when in error. It should be placed in a field envelope together with the hospital record, which is started in this installation. This must state briefly what has been done, date and hour of accomplishment, medication given, any special or unusual features. If plaster has been used, a rough diagram should also be drawn on the cast over the site of injury with the date. Added sedation and amount of intravenous therapy, blood, plasma or expanders should likewise always be noted.

the front line to the hospital in the Zone of Interior has a perfectly definite mission to perform. Deviation from this mission at any point interrupts the whole pattern designed for the care of the wounded with resulting deterioration of this care. The system itself is elastic and may be telescoped or expanded to meet particular situations. With temporary modifications, the same plan provides the same high quality of care in desert, jungle, island, amphibious, urban, or rural warfare. When each unit carries out the mission for which it is designed, both it and the units in front of and behind it develop confidence and trust in each other with the result that each is ready and able at all times to do what it is supposed to do, and there is consequent improvement in continuity of care of the wounded.

Transportation. During World War II and in Korea, the United States Forces never compromised the principle of first priority surgery for the most severely wounded. This was made possible by great elasticity in organization for transport and evacuation of the wounded, flexibility in the utilization of the various medical units and hospitals, and use of auxiliary surgical teams. These teams were employed in all echelons from the Beach Clearing Station in amphibious operations to the General Hospital in the Communication Zone. Their chief employment, however, is in the MASH units, where they are entirely responsible for the surgery, and in the Evacuation Hospitals, where they supplement the surgical staffs.

In addition to the intrinsic transport of the Divisions and their Medical Regiments, separate Ambulance Companies from the Field Army are assigned as needed. These establish loading points all the way from forward of the Collecting Station to the Evacuation Hospital, which, depending upon the rapidity of the combat movement and terrain, may be located anywhere from near a Clearing Station to 60 to 70 miles to the rear, although the usual distance is 10 to 15 miles behind the front line. The Ambulance Control points are in contact with the Evacuation Hospitals as well as the Clearing Stations and MASH units so that the incoming load may be estimated and properly distributed. From the Evacuation Hospitals patients are evacuated to medical holding units for transport by air, to railheads, or even directly to General Hospitals.

The nontransportable group of patients do not tolerate transportation until after resuscitation and initial surgery; hence they are held in the Mobile Army Surgical Hospitals until adjudged safe to travel. Most head wounds, however, stand transportation very well, as do also the properly splinted fractures, soft part wounds, and some of the maxillofacial and chest cases.

Air evacuation of patients, a development of World War II, was greatly expanded in the Korean conflict. It is rapid, comfortable, and safe. Patients may be evacuated from the forward hospitals to hospital centers several hundred miles to the rear with speed and without transfer through other units. In especial situations, moreover, such as prevailed at Anzio, planes may be used for evacuation of even the freshly wounded to General Hospitals in the Communication Zone. Furthermore, the most forward airfields may be made available as soon as they are established for a plane carrying supplies of fresh whole blood from the Base for use in the MASH and Evacuation Hospitals.

WAR WOUNDS — GENERAL CONSIDERATIONS

Of the many articles that have been written about the management of war wounds, perhaps the best summation of the problem is expressed in the opening paragraphs of the War Department Medical Bulletin on the *Care of Battle Casualties:*

> The care of the wounded must always be modified by conditions and circumstances that govern the tactical situation at the moment. It is erroneous, however, to assume that the surgery of war is entirely molded by concessions to the need for haste and confusion of caring for overwhelming numbers of patients. Military surgery is not to be regarded as a crude departure from accepted surgical standards, but rather as a development of the science of surgery to carry out a specialized and highly significant mission. Modern surgical treatment employs many adjuvants to operative techniques, such as chemotherapy, fluid replacement therapy, the transfusion of whole blood and fractions of blood employed as substitutes, potent anesthetic agents and narcotics, [and antibiotics. Ed.]. These tools are as important to the military surgeon as his

and not as definitive therapy in patients who have suffered extensive hemorrhage. The patient who has been in poor condition because of blood loss, with low blood volume and possibly low hematocrit, often will be seriously endangered if his blood (and effective vascular) volume is increased by plasma without hemoglobin being added. Such a patient may superficially appear to be prepared for anesthesia and surgery. The blood volume has been restored and the meager quantity of hemoglobin available diluted. A small further loss of hemoglobin from renewed bleeding or during surgery may be critical and sudden disaster occurs (8).

(c) *Albumin.* The action of albumin is almost identical with that of plasma. Its chief advantage is its small bulk. When it is used, however, intravenous saline solution must also be given to overcome the dehydration that is almost always present and is accentuated when concentrated albumin alone is used, inasmuch as its effect depends on drawing fluid from the tissues into the vessels.

(d) *Expanders.* Plasma expanders such as dextran, PVP (Polyvinylpyrrolidone), and others such as oxypolygelatine may be used in limited amounts probably up to 2,000 ml. as a temporary measure. The only advantage these have over glucose, however, is that they remain in the circulation somewhat longer. Obviously they are not as useful as hepatitis free plasma or albumin or, of course, blood.

(e) *Blood.* Whole blood is the basic therapy in resuscitation and preparation for surgery of patients suffering from hemorrhage or traumatic shock. Evidence of hemorrhage, the pulse, color and temperature of the skin, the facies, and the blood pressure are all important guides to the patient's condition. Both the blood pressure and pulse are deceptive, however, in the early stages of shock; both may be unstable, so much so, in fact, that marked change may occur even on change of position. On arrival at a hospital after a long ambulance ride, the patient may appear to be in bad condition. After a short period of rest in the Trendelenburg position, however, the pulse may return, the blood pressure rise, and the color improve. The most important favorable clinical signs are a steady pulse and a warm, dry skin with prompt return of color on blanching—evidence of adequate capillary circulation. Unfavorable signs are falling blood pressure and rising pulse rate, clammy, cold, and dusky extremities, and restlessness. Treatment should never be delayed pending the result of laboratory examinations.

The speed of administration and the amount of blood to be used depend upon the condition of the wounded man. Although ideally blood of the same type as the patient's should be used, this is seldom possible or practicable and requires the services of the laboratory for grouping and cross matching; the avoidance of such delay may be vital at times. Therefore low titer (iso-agglutinin titer 1:64 or less) type "O" blood is used, as indiscriminate administration of high titer "O" blood may cause considerable destruction of red cells in some recipients of other blood groups (9). In the more serious cases, it will be necessary to give the first 500 to 1,500 ml. rapidly, perhaps even under pressure and by two or more veins. While the first transfusion is running, the patient's blood can be grouped and cross matched for future needs. When the blood pressure begins to rise, the speed of the transfusion can be decreased. After it has reached 80 mm. Hg, the rate of flow should be definitely slowed to 500 ml. every 30 to 60 minutes. This is particularly important in chest and head cases, which should always be kept a little on the "dry side," so as to prevent cardiorespiratory difficulties with pulmonary edema, or increased intracranial pressure. With a blood pressure of 80 to 85 mm. Hg, the patient is ready for surgery. In fact, surgery may be an integral part of resuscitation in the arrest of internal hemorrhage, the repair of ruptured hollow viscera, or the reduction of large eventrations. If surgery must be delayed because of a backlog, the blood pressure should be held at about this level, provided the patient looks well clinically, rather than an attempt made to raise it still further. Added transfusions will do more good during operation and postoperatively, and the risk of starting hemorrhage afresh will be averted. Should the patient's condition begin to deteriorate, surgery should be undertaken forthwith.

Transfusion of whole blood should not be undertaken lightly nor its dangers neglected; it is an exact procedure and should always be

Resuscitation. Resuscitation includes all measures used for the relief of shock in restoring a patient to a relatively normal "equilibrium" so that he reaches a moderately stable condition. This "equilibration" should not lead the resuscitation officer or the surgeon astray, however, as urgent surgery may be too long delayed. The resuscitation ward should be in charge of officers well trained for this work, should be of convenient location to the x-ray and operating wards, and should be thoroughly equipped with all modern apparatus for this most important phase of initial surgery. The resuscitation officer and one of the senior surgeons should maintain constant control of the patients, the amount and timing of plasma (expander) and blood replacement, and the timing of the necessary surgery.

Shock as seen in battle casualties is of three varieties: 1. hemorrhagic and traumatic, which are practically the same and accompanied by similar phenomena; 2. that caused by severe infection, as in overwhelming peritonitis or clostridial invasion; and 3. that accompanying burns. In the first variety there is hemodilution and reduction of the circulating blood volume, whereas in the last two there is hemoconcentration. Blood, plasma and plasma expanders are used for all types of shock, but as in civilian practice, blood is by far the most important. Preparations of norepinephrine should also be available. At times this medication may prove invaluable and even lifesaving as an adjuvant to intravenous therapy.

In burns there is a greater need for plasma to supply early plasma volume deficiency, but whole blood is still essential because of the red blood cell destruction and the resulting anemia. Resuscitation thus begins at the Aid Station with a combination of the measures just outlined. At the Clearing Station the decision is made whether or not the patient can withstand further travel to the Evacuation Hospital. If not, he is carried immediately to the adjacent MASH.

Here a full appraisal of the patient's condition is made and a complete physical examination performed *with good light.* The amount of morphine he has already received is noted as this may be an important factor if he is semicomatose. More than 0.015 gram is rarely necessary, and our present morphine substitutes, such as methadon, are equally as effective. There may be poor absorption from the capillaries in a person in shock, particularly in cold weather, so that if added dosage is given, the combined amount may be suddenly absorbed and signs of poisoning appear. Except for abdominal wounds and some fractures most patients do not have much pain and require relatively little sedation.

The patient is placed in the Trendelenburg position with the foot of the litter elevated twelve inches, unless difficulty in breathing is caused by it. Frequently this alone will bring about considerable improvement. If there is a wound of the thorax, the chest is aspirated of blood and air, the intercostal nerves above and below the wound are injected with 5 to 10 ml. of 1 per cent procaine, and the trachea aspirated if it is obstructed with blood and mucus. If external bleeding has not already been arrested, this is done, and splints are inspected as to their efficacy. The patient is kept warm, but external heat is applied with great care as it is far better that he should be a little cool than too warm.

Fluid. Most injured patients are thirsty. If surgery is imminent, however, it is obvious that water should not be given by mouth and it is, of course, contraindicated with abdominal wounds. Furthermore, if the patient is sensitive to, or has received, morphine, water will probably make him vomit. Gastric dilatation is common in these patients, and there is often much undigested food in the stomach; lavage should be performed, preferably with a large tube.

Intravenous Therapy. (a) *Saline and Glucose.* These solutions are good for dehydration, but they are in no way substitutes for whole blood. They are useful in maintaining the bare needs of fluid equilibrium only if there is to be a prolonged delay before surgery. They may increase intracranial pressure or precipitate or increase pulmonary edema. An already dilute blood is further diluted, and such fluids soon leave the circulation and enter the tissues.

(b) *Plasma.* In seriously wounded patients,

plasma gives more time to get whole blood into the patient. It should be considered as a stop-gap

and not as definitive therapy in patients who have suffered extensive hemorrhage. The patient who has been in poor condition because of blood loss, with low blood volume and possibly low hematocrit, often will be seriously endangered if his blood (and effective vascular) volume is increased by plasma without hemoglobin being added. Such a patient may superficially appear to be prepared for anesthesia and surgery. The blood volume has been restored and the meager quantity of hemoglobin available diluted. A small further loss of hemoglobin from renewed bleeding or during surgery may be critical and sudden disaster occurs (8).

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surrounded with every precaution. When there is time, and except in emergency, cross matching should be performed. If there is any question in the cross match, even when low titer "O" blood is used, the donor blood should also be grouped, as the possibility of human error is always present. Although the Rh-factor is not of the same importance as it is in civilian surgery, it should not be neglected, as occasionally Rh negative individuals are encountered for whom special precautions must be taken. In time of war, hospitals of a Field Army should be relieved of the necessity of drawing the blood required and should be able to call upon the Blood Bank for their entire supply. Sometimes, however, Evacuation Hospitals can maintain blood banks of their own and, when this is possible, donors may be readily obtained from nearby Service Troops and from their own slightly wounded patients or those with minor illnesses.

Time Required for Resuscitation. If the patient fails to show any response, or shows only a very transient one, after 1,000 to 2,000 ml. of blood or after two to three hours spent on resuscitation, something is obviously wrong. The causes for this failure to respond are usually: 1. continuing hemorrhage; 2. massive infection, particularly peritoneal or clostridial; 3. incomplete major traumatic amputation or large eventration of viscera; 4. extensive intracranial damage; or 5. blast injury of the lungs or heart. If any of the first three of the above are suspected, immediate surgery is indicated with continued transfusion, as resuscitation cannot be complete until such necessary surgery is performed. With the last two conditions, it is better to proceed with whatever operative treatment is required than to procrastinate and continue to pour in blood and plasma because in such cases as these, continued intravenous therapy will precipitate increased intracranial pressure or cerebral edema, or cardiac dilatation with pulmonary edema. As to the proportions of blood and plasma used in preparation for and through surgery, the ratio is about two or three 500 ml. units of blood to one unit (500 ml.) of plasma; the more severe the wounds and the shock, the greater will be the amount of blood required.

Anesthesia. The advances in anesthesia have been very great during the past quarter century, so that instead of playing a distinctly ancillary role to surgery, in World War II it assumed an important position and increased considerably the possibilities of surgery. Quite apart from the many difficult technical problems with which he is confronted, the anesthesiologist is also responsible for the training and supervision of his nurse and corpsmen assistants, usually administers all regional and sympathetic nerve blocks, and may be in charge of resuscitation and the preoperative preparation of the major cases.

In the forward hospitals, many problems arise in conjunction with the severely wounded which tax the skill and resourcefulness of the anesthetist; hence, most of the best anesthetists should be in these installations, although some supervision and training must be maintained in the rear areas. A number of variables influence the choice of anesthetic agent: (*a*) type and condition of patient, (*b*) type of injury, (*c*) volume of work and tactical situation, (*d*) personnel available, (*e*) equipment and location, and (*f*) previous medication:

(*a*) The patient is a young, healthy male when wounded; he is well fed and well trained and has enormous powers of recuperation even from most severe trauma.

As opposed to these favorable factors, he may be gravely wounded and suffering from exhaustion, long exposure, and severe shock and hemorrhage. The wounds are frequently multiple, and extensive infection may already be present. These unfavorable factors are almost always encountered in the MASH units, less often in Evacuation Hospitals.

The *condition of the patient* in regard to loss of blood, shock, disturbed physiology, etc. is also important.

(*b*) Each type of injury presents its own problems. The *location of the wound* or wounds has its own indications or contraindications regarding the agent to be used.

(*c*) The *volume* and *pressure* of work and the extent of the surgical backlog, along with the existing military situation as to the needs of evacuation or possible impending move of the hospitals—all these must be considered.

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Before any general anesthetic is administered, the stomach should be emptied for frequently there is much undigested food present, which should be removed by lavage or induced vomiting when feasible. Oxygen may be more effective in quieting a restless patient with badly disturbed cardiorespiratory physiology than morphine. Atropine should always be given before anesthesia to diminish secretions and, when pentothal is used, to prevent laryngeal spasm. Scopolamine is contraindicated in forward surgery because of its amnesic and hallucinatory properties.

The anesthetic agents most suitable for use in forward surgery are: (*a*) procaine and pontocaine, (*b*) nitrous oxide, (*c*) ether, (*d*) sodium pentothal, (*e*) vinyl ether at times, for short anesthetics or induction. In most forward areas nitrous oxide will be dispensed with because of the logistics problem created by the weight of the tanks.

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(*b*) *Nitrous oxide* is useful alone for very short procedures. Its chief values are that it is an induction agent for ether, it can be administered with sodium pentothal and 50 per cent oxygen, thereby reducing the amount of pentothal required, and it is noninflammable. It is the least essential of the agents used in forward hospitals and may be readily sacrificed when transport is at a premium and supply difficult.

(*c*) *Ether* is still the most useful of all anesthetic agents. It is the safest, packs and transports readily, is administered easily, and is the best agent at present for patients suffering from shock or hemorrhage, for those with thoracic, abdominal, or extensive wounds, and also for many with head and maxillofacial injuries. Nitrous oxide, pentothal, ethyl chloride, vinyl ether, or chloroform may be given for induction, or ether itself may be used for this purpose in the severely *injured. The anesthesia may be* perfectly controlled at any plane, and a high percentage of oxygen, which is so necessary in shock and wounds of the head, chest, and abdomen, may be provided throughout. Endotracheal administration is particularly valuable for this same group of patients, with the added advantage of better aeration, control of respiration, and aspiration of the trachea and primary bronchi. There is no respiratory depression and patients react promptly, which is important for the patient and in greatly facilitating nursing care.

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tality attributable to it was 1:450. As its limitations became appreciated and its contraindications accepted, more judicious selection of cases was made, with the result that it soon became recognized as a most important agent for anesthesia in forward surgery, and its mortality rate dropped to one out of every 5,500 cases in which it was used (10). Pentothal abolishes the normal CO_2 mechanism of stimulation of the respiratory center and throws the whole burden on the response of the carotid sinus to anoxia. It is a marked respiratory depressant, and when it is given, high oxygen content of the blood is essential and oxygen rather than CO_2 must be used to bring about improvement in respiration. As pentothal may also produce laryngeal spasm, premedication with atropine is mandatory and the dose should be repeated intravenously if spasm occurs.

Sodium pentothal in 2.5 per cent solution is ideal for operations of not over 45 minutes. If longer anesthesia is required, it should be combined with nitrous oxide-oxygen, 50 per cent each, or a shift made to ether. It is contraindicated in severe shock or extensive hemorrhage, in cases of anaerobic myositis, in abdominal and intrathoracic wounds, in conditions involving the neck and mouth because of its action on the carotid sinus, and in intracranial operations because of its tendency to anoxia. For these last three groups of cases, as well as for many wounds of the neck and face, endotracheal ether is the anesthetic of choice.

(*e*) See ether (*c*).

A sampling of 44,530 anesthetics given in Seventh U. S. Army hospitals from November 1, 1944, to April 30, 1945, is typical of the differences between the field and evacuation hospitals. All of the former were working adjacent to the Division Clearing Stations and so received only the nontransportables and most severely wounded (11).

Basal anesthesia with avertin or paraldehyde and rectal ether have no place whatsoever in military surgery in forward hospitals.

Operative Treatment. The concept of war surgery has been clarified by Churchill (7), each phase defined and its mission explained.

> Wound management may be divided into three phases—initial, reparative, and reconstructive. The first two are concerns of an overseas theater. The latter is the mission of the Zone Interior. . . .
>
> The initial wound operation is directed toward the prevention of infection by a complete excision of tissue devitalized by the missile. Procedures such as closure of a sucking wound of the chest or suture of a perforation of a hollow viscus restore physiologic equilibrium as well as arrest the dangers of infection. Recognition of all devitalized tissues is oftentimes impossible, particularly in a massive wound or one complicated by skeletal injury. Disturbances of blood supply and subtle changes that indicate impending death of tissues may not be detectable. In a certain number of these cases mixed anaerobic infection of residual dead tissues is the inevitable sequella. Others will develop invasive infection spreading from the wound to involve normal tissues. To minimize the incidents and hazards of infection, primary closure by suture is strictly avoided. Exact maintenance of the reduction of fractures by precise methods is precluded by the necessity for evacuation to the rear, so temporary or transportation splinting, usually with plaster of Paris, is employed (7).

So important is the initial débridement that the whole future course of the wounded

TABLE 2.

	(MASH) FIELD	EVACUATION
Inhalation	2,148—86.2%	9,762—23.2%
Field Blocks	45—01.8%	4,904—11.6%
Miscellaneous Regional	117—04.6%	558—01.3%
Spinal	11—00.4%	383—00.9%
Sympathetic	44—01 8%	319—00.8%
Sodium Pentothal (intravenous)	71—02 9%	22,363—53.1%
Intravenous Combined	56—02.3%	3,849—09.1%
Total	2,492	42,138
Endotracheal (Evacuation Hospitals)	3,042	(31.1% of inhalations)
Endotracheal (Field Hospitals)	1,782	(82.9% of inhalations)

soldier may well depend on the care and the completeness with which this is performed. The literal translation of *débridement* is *incision*. The French describe the trimming of excision of wounds as *épluchage* and *parage*. In our comprehension of the term, however, débridement of a wound means complete excision as far as possible of all damaged or devitalized tissues, and removal of all foreign bodies, dirt, and small, completely unattached bone fragments. The initial incision must be bold and ample and the fascia split widely in a longitudinal direction. Good lighting, free retraction, and a dry field are essential. Compromise must be made, of course, with major nerves and arteries. Particular attention should be given to muscles and fascial planes, and less to skin, which requires minimal excision, and bone ends should be thoroughly cleaned and rongeured, if necessary. All recesses are opened and explored. Bleeding vessels should be ligated carefully with only the smallest amount of tissue included in the ligature and fine ligatures used and the ends cut short. The tissues, already traumatized, are handled with great gentleness. The wound is left unsutured and dressed with a layer of *fine-mesh* plain gauze, which is not stuffed or plugged in but merely laid over the edges to the depth of the wound. When plain fine-mesh gauze is used, the wounds appear fresher and drier at the first dressing than when petrolatum gauze has been used. A properly débrided wound is dry and bleeds readily, its muscle appears red and contracts normally, it appears clean and contains no hidden pockets. If a cavity in the tissues is left, as around the site of a fracture, and puddling seems likely, counterincision at the most dependent point should be provided at the time of débridement so as to permit drainage of the wound secretions. If the wound is extensive, even though no fracture is present, immobilization in plaster of Paris should be provided.

Just as plasma is not a substitute for whole blood in resuscitation, neither are sulfonamides and penicillin [antibiotics—Ed.] substitutes for the surgical excision of devitalized tissue. Chemotherapeutic agents cannot sterilize dead, devitalized, or avascular tissues nor do they prevent the septic decomposition of contaminated blood clot (7).

Local use of antimicrobials in wounds is not recommended, except in joints. A combination of penicillin and streptomycin or a broad spectrum antibiotic has probably already been given at the Battalion Aid or Clearing Stations. This medication is continued at the hospital throughout the surgical and early postoperative period. In most instances antibiotics are preferable to chemotherapeutic agents because: 1. they are more effective against the common types of wound infection; 2. they produce no renal complications; 3. they do not interfere with the appetite; 4. they do not add to an already present anemia. Sensitivity must be considered, particularly with penicillin. One of the soluble sulfonamides is indicated, however, when an indwelling catheter or suprapubic cystostomy has been necessary. The antimicrobials used in conjunction with exact and complete débridement add to the possibilities of initial surgery but are in no way a substitute for it.

The magnitude of the surgical problems that confront the forward surgeons when supported by adequate resuscitation therapy is difficult to visualize by one not having a firsthand acquaintance with their work. Highest standards of precision must be maintained if the potentialities of surgery are to be realized to full advantage. This precision must be attained in the use of adjuncts to surgery as well as in operative technics. Initial surgery cannot be carried on as a hasty, slapdash and bloody spectacle, with rapid evacuation of the patient to the rear if satisfactory *results are to be achieved* (7).

Postoperative. In the Mobile Army Surgical Hospitals, except for the resuscitation ward, there is no special area designated as a postoperative ward. All of the patients in this hospital, when it is utilized properly, are seriously ill in the immediate postoperative period and are under the constant supervision of nurses and highly trained corpsmen, with the members of the medical staff likewise in constant attendance. Each ward is equipped for postoperative emergencies with adequate suction, provision for intravenous medication, oxygen equipment, tracheotomy sets, water, and heat and good light. In Evacuation Hospitals, postoperative wards are established where the patients are held as long as possible following operation and where

such special care and equipment as outlined above are always available.

Reparative Surgery. This is carried out in the General and Station type Hospitals in the Communication Zone to which patients are evacuated from the Field and Evacuation Hospitals of the Field Army. "A highly significant and far reaching advance in military surgery has taken place in the base hospitals with the development of what may be called *reparative surgery*. Wounds left unsutured at the initial operation are routinely closed by suture, usually at the time of the first dressing" (7).

If the original débridement has been properly performed and the patient promptly evacuated, the initial dressings are removed in the operating room of the base hospital between the fourth and tenth day. If the wound appears clean and without sign of infection, it is sutured without any freshening of the edges or cleansing of the wound other than the gentle removal of fresh blood and clots. Or the closure may be staged, with closure of muscles and fascia as the first stage, as in very large wounds of the back and shoulders, and skin closure deferred to a later date. Tension and strangulation of tissues must be avoided; otherwise, failure is inevitable. Later than ten days the skin margins will have to be freed and the ends of the wound may be extended with curved or "Z" incisions and flaps formed. With simple closure no added therapy is required, but with the more complicated procedures parenteral antibiotics may afford protection from infection. If at the first dressing there is redness or evidence of foreign bodies or slough, moist dressings are applied for a few days or the wound is redébrided and moist dressings applied.

The same principles apply to the more extensive wounds. When these patients are received in the base installations, their secondary anemia is corrected by transfusions and their casts removed and fractures reduced so as to obtain good alignment and healing. If débridement of these compound fractures and joint wounds is incomplete, the wounds are explored and all dead and infected tissue, foreign bodies, and sequestra of bone and cartilage are removed under the protection of antibiotics and transfusions as necessary. If good healing is obtained, such wounds may be reopened safely in two to three weeks for the suture of nerves or internal fixation of fractures.

In wounds of the chest, attention has been focused on restoration of the normal physiology with immediate re-expansion of the lungs and repeated aspirations or water seal drainage to maintain it. As these patients reach the base hospitals and centers, the procedures already initiated are continued and supplemented by drainage, or later by complete decortication of the lung. With transfusions and antimicrobials, radical surgery may be performed in from three to six weeks with the expectation of primary healing and complete lung re-expansion. In a series of 870 penetrating chest wounds treated by Burford in a chest center, 752 were accompanied by hemothorax and 111 of this group became infected. Only four of these patients were returned to the Zone of Interior for further treatment of their empyemas. The others were either returned to duty within the theater or required evacuation to the Zone of Interior for other reasons (12).

Patients with abdominal wounds usually reach the base within about two weeks after their initial surgery and frequently present most difficult surgical problems. Anemia and electrolyte and fluid imbalance have to be overcome and small intestinal fistulae closed. A certain number of these patients develop early intestinal obstruction. Some need revision of colostomies, and in some the colostomy may be safely closed with the expectation of a return to duty in the theater.

Although reconstructive plastic surgery belongs in the Zone of Interior, it should always be remembered that skin is the best dressing there is. Any area, therefore, that cannot be closed by suture or sliding flaps should be covered as early as possible with split thickness grafts even though later revision may be required. The early closure of wounds by suture or graft not only diminishes hospitalization but reduces the deep scarring and fibrosis that will otherwise occur, and it also makes possible the early return of thousands of troops to duty, who otherwise would be returned to the Zone of Interior.

Infection. All wounds are contaminated, but the transition between contamination and

infection is an ill-defined borderland. In the past an empiric period of six hours has been stated as the "golden period" during which infection need not be considered as an important factor in a fresh wound, but after this time wounds should be considered to be frankly infected. While this may be true with the majority of wounds, it does not apply to those of the trachea, mouth and hollow viscera, which are infected from inception.

To understand the nature of wound infection, it is necessary to distinguish between bacterial growth limited to the tissues that were devitalized by the injury and invasive infection that starts in the wound and extends to living tissues. The former may be termed surface infection with injury necrosis; the latter, invasive infection (13).

The common pathogenic and saprophytic bacteria are present in wounds and take part in the natural processes of proteolysis and digestion, which lead to the separation of dead tissue, sequestra, and the extrusion of foreign bodies. Mechanical, chemical, and biologic aids are frequently used to assist in this process: physiologic saline irrigations, sodium hypochlorite or Dakin's solution, urea, enzymes such as streptokinase and streptodornase and perhaps some of the collagenases. Antiseptics used to "sterilize" and stimulate wounds, while they may kill surface bacteria, also kill tissue. If the slough is thick, there will be no penetration of the wound at all by these chemical agents, and hence the desired antiseptic action will be nil. But, on the other hand, if the "antiseptic" really helps to separate the slough, it also comes in contact with viable tissues and "stimulates" them into a fresh layer of slough by its necrotizing action, or, by its irritant effect, increases wound secretions. Such agents should always be used purposefully to attain a specific end, not just on the general principle that it is good to kill all bacteria.

The almost inherent urge to place some agent, with hopeful healing and anti-infective properties, in a wound seems to be deep-seated in the human breast and is as difficult to control as the better recognized human impulses. Time and experience have repeatedly demonstrated the inefficacy of such agents. Perhaps some day such an agent will be found but the search seems futile when it is realized that the key to wound infection in traumatic wounds is dead tissue, a fact which Botallo recognized almost four centuries ago, and which Lister fully appreciated (14).

Years ago Lister taught that:

> All the local inflammatory mischief and general febrile disturbance which follow severe injuries are due to the irritating and poisonous influence of decomposing blood or sloughs (15).

In the presence of dead tissue and tissue with an impaired blood supply, anaerobic bacteria are predominant, and the most important of these are the *Clostridia perfringens* (*Welchii*), *oedematiens*, *septicum* and *sordelli*, and anaerobic streptococci. Infection with these organisms may be local and limited to the area of the wound, or in deep wounds local pockets may be formed in the wound track or in nearby fascial spaces, which sometimes contain gas under pressure, the "gas abscess." This type of infection is apt to occur in wounds in which initial surgery has been delayed.

Invasive infection starts in the same manner and spreads by direct extension into muscles, along fascial planes, and along vascular sheaths. Lymphangitis and involved regional lymph nodes are seldom seen; metastatic infection and septicemia originate from infected thrombi or from erosion into a damaged vessel.

The anaerobic infections that are limited to the fascial planes and connective tissue have been designated anaerobic cellulitis. The patient may appear acutely ill with high temperature and other signs of absorption of toxins. The pulse is usually disproportionately low in comparison with the temperature, however, and there is not the overwhelming prostration noted in clostridial myositis. There may be signs of localization or evidence of extensive progression of the infection. Anaerobic cellulitis usually responds well to wide incision and drainage and excision of all necrotic tissues along with parenteral antibiotic therapy.

Gas Gangrene. When the clostridia invade the muscles themselves, the picture is quite different and is one of true "gas gangrene." This term has been replaced by the more specific term *clostridial myositis*. The infection appears in two forms, the dry and the wet. The dry form is usually associated with *Cl. perfringens* and the wet with *Cl. oedematiens*

or *sordelli*, but frequently there is a mixed flora of these bacteria along with anaerobic cocci and the common pyogens. Compound fractures of the long bones and wounds or thrombosis of the major arteries of the extremities are important predisposing factors, and the lower extremities are most commonly the site of infection.

The best preventive against clostridial myositis is early and adequate débridement with nonsuture of wounds; this means free skin and fascial incisions so as to prevent the development of tension in the wound. There must be *no* circular or constricting dressings. Whenever the patient complains of sudden onset of pain in his wound, the wound should be redressed at once, as sudden pain is the most common symptom of the onset of clostridial myositis. Other early symptoms and signs are loss of appetite, personality changes, and prostration and hemorrhage from the wound. The condition often makes its appearance with dramatic suddenness and profound prostration and runs a fulminating course. Contrary to its character in anaerobic cellulitis, the pulse is disproportionately high in relation to the temperature, and the toxemia is profound, with rapidly developing anemia and signs of shock. There is marked swelling, there may be color changes and crepitation, and in the wet form the tissues are wet and soggy. The treatment is surgical and consists of wide incisions and excision of all involved muscle bellies. Amputation is necessary only when the circulation is so impaired that survival of the limb is doubtful, or if there is so much bone or muscle destruction that the limb will be useless anyway.

Penicillin is recommended in dosage of 1 million units intramuscularly every three hours, or tetracyclines are used in dosages of 0.5 grams intravenously every eight hours, or 0.2 grams every six hours intramuscularly. Antigas serum as presently developed or hyper-immune serum is of questionable value; primary reliance must be placed upon adequate surgery and control of the accompanying aerobic infection with antimicrobials.

Statistics on anaerobic cellulitis and clostridial myositis are confusing and not too reliable, particularly because the two conditions have not been well differentiated. In World War I the incidence of gas gangrene was 1.7 per cent (1.08 per cent for wounds of soft parts only and 6.26 per cent in cases complicated by fracture) and the mortality was 46.6 per cent. The Seventh Army in reporting 46,600 U.S. battle casualties from November 1, 1944 to April 30, 1945, in France and Germany, had 152 clostridial infections with 90 amputations and 38 deaths; the incidence in this series was 0.3 per cent of all wounds and the mortality 24 per cent.

Tetanus. Due to the increasing widespread inoculation with tetanus toxoid in early childhood with booster doses continued, tetanus is no longer the major problem it once was. Nevertheless, an occasional neglected patient is admitted to the medical services with this dread disease. If the patient is a member of the armed services or is otherwise known to have had tetanus toxoid previously, a booster dose is immediately given when he is first received in a medical facility. If he has never had tetanus toxoid, then he should be tested for sensitivity and a large dose of tetanus antitoxin given. The usual prophylactic dose of 1,500 units is useless in war wounds. This should be raised to the level of 6,000 to 9,000 units initially, and at the same time the wound should be thoroughly débrided, or excised if possible (16). Once the disease has established itself, therapy has little more to offer today than it did many years ago. It is largely supportive in nature, with sedation and adequate alimentation by vein or by gavage. After prompt testing against horse serum and desensitization if necessary, very large doses of tetanus antitoxin intravenously should be given, such as 60,000 to 100,000 units initially and 50,000 to 75,000 units at 24-hour intervals.

Recent experiments with small animals suggest that large doses of the tetracyclines may also be of distinct benefit in treatment.

Bactericidal and Bacteriostatic Agents. These have already been referred to and the basic principles underlying their use stated. All hark back to 1870, when Lister suggested that the skin be washed thoroughly with a 1:20 aqueous solution of phenol, all bleeders tied, no sutures used, and the wound covered with dressings soaked in a 1:5 solution of phenol in oil, which was changed the following day to a 1:10 phenol in oil dress-

ing and then to a 1:20 dressing (17). In World War I the surgeons still sought the ideal antiseptic, hence Dakin's solution of the exact pH so that injury to living cells would be minimal, but the solution itself is too unstable to attain this objective. Because a correctly performed Carrel-Dakin dressing is almost impossible of proper execution in a mobile hospital, where numbers of open wounds require daily dressings under this treatment, other antiseptic dressings in the form of pastes were advocated. Only toward the end of the war was it fully realized that the primary requisite for wound healing was the initial removal of all dead tissue so that a clean wound was left.

In the early stages of World War II, great hopes were placed in the sulfonamides, but it soon became apparent that they were of no avail per se in preventing infection in the presence of dirt, sloughs, dead tissue, and sequestra. And so it was again with penicillin. It became evident, however, that these antimicrobial agents might be used singly or in combination, and when so employed they extended the scope of surgery considerably, especially when initial surgery had been long delayed. When employed in this manner, they are particularly valuable in the field of reparative surgery but have no place in encouraging a "safe" period of delay.

The more thorough the débridement and the necessary surgery, the more helpful will be the antimicrobials. They are always an adjuvant, never a substitute or a cure in themselves. They should always be administered knowingly and with judgment and should be terminated as soon as possible because of real dangers associated with them. Unfortunately, penicillin at times creates sensitivity which may be most serious and even threaten life itself. The action of streptomycin on the intestinal flora and the *Escherichia coli* is of short duration with prompt escape of the bacteria from its control. Neomycin when administered orally and used in conjunction with streptomycin enhances the action of both. It cannot be given parenterally, however. Some of the broad spectrum antibiotics may occasionally induce agranulocytosis and also, by limiting the growth of the customary intestinal flora, may encourage the growth of intestinal monilia, with most distressing symptoms and a condition that at times does not yield readily to treatment. Perhaps one of the gravest of all the complications of our present widespread use of the antibiotics is the persistence of a resistant coagulase positive hemolytic staphylococcus. This is a highly virulent pathogen, and these infections, of which the most common are pneumonia, septicemia, and necrotizing colitis, are most difficult to treat.

Dressings. Dressings should be done infrequently, gently, and carefully, and one should never hesitate to transport a patient to the dressing tent or operating room if he can be moved and the dressing can be better performed there. Under ideal conditions the first dressing will be performed and the wound sutured in the operating room between the fourth and tenth days; the second dressing will be 10 or 12 days later when the sutures are removed. Masks should be worn for all dressings, even in the most forward hospitals; this precaution is a most important preventive of droplet contamination, which may of itself lead to wound infection.

Convalescence. Convalescence and rehabilitation are integral parts of military surgery. The greater the number of men who can be restored to duty within the Army area itself, the higher will be the morale of the troops. This is achieved by means of convalescent hospitals. Forward (Army) hospitals have a three-fold function: 1. to provide expert care for the wounded; 2. to provide for and keep clear the chain of evacuation so that they are able at all times to receive the oncoming load from the front; and 3. to hold as many as possible of the ill and minor wounded so as to assure their return to their own units with a minimum of delay and confusion. At times of great stress, such as an amphibious operation or the first phase of an offensive, it may be necessary to evacuate almost every one who is transportable. Again, during periods of quiet such as usually occur in winter, many can be held for two or three weeks in the forward hospitals. Various ancillary hospitals are employed to expand such a holding policy. These have a double action: first, more beds are provided; and second, by segregating similar groups of patients, the morale of these particular

groups as well as the morale of the others is improved. Thus we have the convalescent hospital, with skeleton staff and minimum equipment. When it is broken up into sections, the small units can move rapidly and act independently or be temporarily attached to an Evacuation Hospital. These units have reconditioning programs and provide for the care of some of the ill and minor wounded for 20 to 30 days after they have been discharged from one of the active hospitals. Likewise, venereal disease and neuropsychiatric centers are established by an army operating in the field so that these important groups may be immediately segregated and the patients in the other forward hospitals protected from the destructive effect of these cases on their morale. Simultaneously, by the establishment of these centers, professional care is concentrated and economized, with the result that the patients are much better cared for than if dispersed. One U.S. Army reporting for the period from September 1, 1944, to May 7, 1946, in France and Germany showed a return to duty of 40 per cent of all admissions in its own forward installations: 56 per cent of the "disease," 36 per cent of "injuries," and 16 per cent of "battle casualties" (11).

COMBAT ZONE SURGERY

General Considerations. Prior to consideration of the various types of war wounds individually, one should understand that this section deals entirely with the forward surgery of the wounded, where the primary goals are: 1. arrest of hemorrhage; 2. correction of grave physiological disturbances; 3. prevention of infection. These accomplished, the patient is transported out of the forward area as soon as his condition permits. The greater and more rapid the dispersion of patients to the base, the sooner reparative surgery can be instituted and the better the chances for recovery with good function and minimum deformities. In certain instances, as in abdominal and chest wounds, the initial surgery may of itself be definitive. Thus, the measures listed below must be considered with understanding of the above: the colostomy, the suprapubic cystostomy, and various other procedures recommended such as nonsuture of tendons, nonclosure of amputations, thorough and complete débridements, nonsuture of nerves, the immobilization rather than the perfect reduction of fractures, the initial treatment of major burns by the closed method. Although these measures may seem incomplete, they are those that have been tested by time and experience and have been proved to be the best procedures for this initial surgery.

Surgery in forward areas can always be expanded depending upon the tactical situation at any given period of time. This decision must be made by the Army and the Theater Surgeons, and the various medical installations in turn must abide by it.

Extremities. War wounds of the extremities, which comprise 61 per cent of the body area, account for about 65 to 70 per cent of all wounds. These wounds are simple or complicated depending upon whether they involve only the soft parts or include also bone, major arteries or nerves, joints, or communicate with other regions of the body. All combinations occur. The principles of complete débridement, with splinting when necessary, apply explicitly to the uncomplicated soft part wounds. With early delayed suture this is the largest group of casualties that may never require evacuation from the Army area.

The wounds of open (compound) fractures are débrided and dependent drainage established, when indicated, to prevent pooling of secretions. The object in the forward installations is not to reduce the fracture but to immobilize it promptly and completely in a plaster of Paris transportation cast. Skin-tight plaster is never used and all casts, and circular bandages under casts, are split after application. A rough diagram is drawn on the cast showing the fracture, the size of skin defect, and the date of application of the cast. Internal fixation is used in the forward hospitals at the time of initial surgery *only* when there is danger of impingement of the bone ends on major vessels or nerves, and in some fractures entering into joints when early reduction and fixation are essential to preserve the joint. Débridement of compound fractures of the femur is facilitated by insertion of a pin through the tibia and suspension of the leg, with the knee flexed at 90 degrees, to a frame over the operating table.

These patients are listed as first priority

for evacuation so that they may reach the fixed installations in the Base as early as possible compatible with their ability to withstand travel. Here the condition is appraised and adequate transfusions are given to restore the hemoglobin and hematocrit to normal limits. Casts are removed, wounds sutured or redébrided preparatory to suture, and fractures reduced by whatever means are deemed advisable.

Peripheral Nerves. War injuries to peripheral nerves include contusion and division, with or without loss of substance. Damage from the concussion effect of missiles, with resulting palsies, may occur though no gross evidence of the injury may be seen at the time of operation. When nerves are found divided, no attempt to approximate the ends by suture is made at the original operation, even though in certain instances this would appear to be the ideal procedure. The reasons are that at the time of initial surgery: 1. one cannot determine the extent of possible added nerve damage due to concussion; 2. as little foreign material as possible should be left in the wound; and 3. the frequent necessity of leaving sutured nerves under tension and uncovered in débrided wounds courts further disaster. One of two methods is, therefore, employed at the initial operation: 1. the nerve ends are simply stitched separately beneath adjacent muscles, without tension, or 2. the nerve ends are brought together loosely with a single suture and then protected by overlying tissues. By using wire sutures, the position of the nerve ends can be determined by x-ray, and the size of the gap to be closed can be demonstrated. The extremity is properly splinted, and a careful record of the procedure is made. In the fixed hospital in the Base secondary suture of the wound is done, and two or three weeks after it is fully healed, definitive nerve suture may be performed. At this time degenerative changes will be fully apparent, and an appropriate amount of the nerve can be resected.

Arteries. Major vascular injuries probably complicate about 0.9 to 1.5 per cent of *all* wounds, and between 1.4 to 2.7 per cent of extremity wounds. They seriously complicate (7, 11) the surgical problem in that they threaten the viability of the limb itself, they favor clostridial infection, and, later, they may lead to aneurysms, which usually become the problem of the reconstructive phase of military surgery.

Few of these wounds are simple; the great majority are complicated by comminuted fractures and extensive tissue damage. The wound of the vessel itself is often extensive, and there may be extensive thrombosis already present when the patient is first seen. Sometimes in the absence of an open arterial wound due to contusion, there may be damage to the vessel wall with thrombosis.

Numerous procedures have been advised and devised to circumvent these difficulties and furnish a new arterial segment or to provide temporary circulation until the collateral system can take over. But no amount of reconstruction will avail if the limb distal to the point of injury is already dead. Unfortunately, since most of the injuries are extensive and there is often no choice other than a graft of some sort or ligation of the artery, the injuries suitable for arterial suture and those in which prostheses or grafts may be employed are relatively few, for two reasons: 1. the extent of the damage itself, and 2. the time factor, as it is rarely possible to save the limb by restoring its circulation after eight to ten hours have elapsed from the time of wounding. Every effort should be made, however, to obtain a primary suture or the use of vein graft, or an arterial graft if such is available. If a vein segment is used, this should be reversed so that its valves do not impede the arterial flow. Just as we have blood banks, it is now possible to have blood vessel banks or to use artificial prostheses, such as those made out of nylon, dacron, or similar materials. While successful for large vessels, these have not proved as successful for the smaller. Perhaps the best of these artificial prostheses at present is the Edwards-Tapp, of crimped nylon. Again here the tactical situation and the type of warfare play an important part. This surgery may or may not be possible in the Mobile Army Surgical Hospital, for in war, one must never lose sight of the fact that in the initial surgery of the wounded, the saving of limbs is always secondary to the saving of life.

If the popliteal artery is ligated, 70 to 75 per cent of these patients will require amputation, and about 50 per cent following liga-

tion of the superficial femoral artery (11, 18, 19).

Sympathetic block or sympathectomy has its greatest value when the limb has been ischemic for a period of time and shows very slow recovery after repair of the vessel. After ligation of a major artery, the question of ligation of the accompanying vein arises. Wounds are so different and so complicated, it has been impossible to make any comparison in similar groups where the accompanying vein has been ligated with groups where it has not. If it is ligated, however, it should be cleanly divided after ligation.

Amputations. Closely associated with vascular lesions is the problem of amputations. The great majority will be performed for extensive trauma and are really the completion or temporary revision of traumatic amputations or the removal of limbs attached by only a few shreds of tissue.

"There are three major reasons for amputation—a hopelessly mangled limb, infection and vascular insufficiency" (13). In World War II vascular insufficiency was the reason for amputation more often than infection, or infection and vascular insufficiency combined. Everything is done to preserve as much stump length as possible, prevent infection, and render later revision easy should it prove necessary. These objectives are best attained by the modified circular amputation, which should present a slightly concave open cross section of the extremity at completion. A circular incision is made through the skin and the skin is allowed to retract; the fascia is then incised at this level and the superficial layer of muscles cut and permitted to retract; finally, the deep layer of muscles is cut at this level and the periosteum of the bone is incised, but not stripped, at the level of muscle retraction, and the bone cut through. Skin traction is applied with the original dressing. Continued skin traction of about five pounds is most important in the postoperative period to preserve maximum length, prevent retraction of muscles and skin, and provide a firm covering of fibrous tissue for the end of the bone.

Joints (20). The principle of débridement applies with particular emphasis to joints. They are poorly vascularized structures, their cartilage is prone to infection and necrosis when injured, and drainage of suppurative processes in them is very unsatisfactory. By thorough débridement, bad results can be prevented in the vast majority of cases. All penetrating wounds of joints or compound fractures communicating with joints should be widely explored, with good retraction, so that the joint may be completely visualized. The joint is irrigated with saline solution, all blood clots, loose bone and cartilage fragments, and foreign bodies are removed, and ragged areas of cartilage are pared smooth. The joint capsule is then closed and antimicrobials in saline or water instilled; the skin is not sutured. Plaster immobilization is provided. For the knee joint this means a low spica, as a simple long leg cast does not provide sufficient immobilization. After 48 hours the joint is reaspirated and the antimicrobial agent again instilled, and the process repeated at 48-hour intervals until there is no significant accumulation of fluid. Even though a joint is suppurating when first seen, careful débridement and the treatment decribed should be carried out, for frequently even already infected joints will respond to this therapy provided they are first rendered physically clean. Two Evacuation Hospitals reported 227 arthrotomies for penetrating wounds of the knee with only two residual infections, one 10 and one 14 days old when received by them and both well established at that time (11). The knee of all the major joints is one of the most commonly injured and one of the most successful to treat.

The same principle of débridement applies to wounds of the hip joint. If these wounds are not properly débrided and the joint closed, a severe debilitating infection usually occurs, with eventual osteomyelitis and destruction of the joint if the patient recovers. The best approach to the joint is either by the usual anterior Smith-Peterson or a posterior approach. The joint is exposed and a thorough débridement is performed. Inasmuch as the blood supply comes in through the posterior capsule, this should not be disturbed unless badly damaged itself.

Although the results with the hip joint are inferior to surgery of the knee, nevertheless thorough débridement and installation of an antimicrobial agent will probably prevent a suppurative arthritis and the septic

complications that so often occur with this type of injury. Even if later the head of the femur undergoes an aseptic necrosis or traumatic arthritis, the problem in reconstructive surgery is far less and the outlook better than when incomplete initial surgery is performed.

Craniocerebral Injuries. The head, face, and neck comprise 12 per cent of the body area, and approximately the same percentage of wounds will be found in these regions. The craniocerebral group alone forms about 8 per cent of all wounds. Inasmuch as the vast majority of these injuries are of the penetrating variety, a decompression is often already present when the patient is first seen, and the problem of intracranial pressure is, therefore, of considerably less moment than it is in civilian practice. Furthermore, most of the patients stand transportation extremely well prior to surgery but not at all well in the early postoperative period. It is of the utmost importance that the initial surgery be complete in these patients; hence, they should be sent to installations where facilities, time, and provisions for postoperative care are available. Initial surgery may be safely delayed even up to 72 hours. Following operation, however, they should not be moved for a week or ten days. When débridement is performed, great care is exercised to remove all devitalized tissue, spicules and fragments of bone, and all foreign bodies, especially those other than metallic, although these, of course, are removed also whenever feasible. Every effort is made to close the dural defect, by fascial or preserved dural graft if necessary, and the wound is closed by primary suture. These wounds form one of the few exceptions to the dictum that wounds should never be closed primarily, because, unless primary closure is accomplished, infection and cerebral fungi are prone to occur with ensuing cerebritis. The majority of infected wounds and brain abscesses seen later in the Neurosurgical Centers in the Base are due to the presence of foreign material, particularly retained bone fragments.

Spinal Cord Injuries. This is an extremely difficult group of injuries for treatment, particularly as to laminectomy. In one series of 113 patients operated upon, the mortality varied from 0 to 33 per cent in different hospitals, while in a nonoperative group of 69 patients, the mortality varied from 0 to 66 per cent. Operation itself, therefore, does not appear to be a factor in the mortality. Improvement was noted following laminectomy performed as late as 17 days after injury in a patient who had shown no prior signs of recovery (11).

When patients with spinal injuries are received in the forward hospitals, suprapubic cystostomy should always be performed if bladder paralysis exists. In active warfare, suprapubic cystostomy is the procedure of choice because it is the safest device, requires least care, and is the most foolproof, all of which are essential in ensuring safe and comfortable transportation for the wounded soldier.

Eyes. Wounds involving the eyes frequently require the combined skill of the ophthalmic, maxillofacial, and neurologic surgeons. Fortunately they are not numerous, probably under 5 per cent of all wounds. A local anesthetic applied topically in the Aid Station, the use of atropine, a bland ointment, and immobilization of both eyes by pressure pads and bandages ensure safe transportation to the hospital. Only those eyes that are obviously irreparably damaged should be removed in forward installations. The use of conjunctival flaps is sometimes of great benefit until the patient reaches the Base.

Maxillofacial Injuries. Maxillofacial wounds account for about 4 per cent of all wounds. After thorough débridement and saline irrigations, wounds involving the mouth and face should be sutured with careful approximation of the parts when possible. Great ingenuity is often demanded in the initial surgery so as to prevent infection and conserve tissue, both vital for later repair. Fractures of the jaws should be maintained by wiring, and elastic bands used to hold the wired jaws together, as they are readily removed in case of vomiting. If there are bony defects or the fracture is extensive, contour may be preserved by internal fixation apparatus or a double pin external fixation apparatus. Assurance of an airway must be provided, and tracheostomy may be necessary. Dependent drainage is advisable, and moist dressings help in controlling possible infection. Parenteral antibiotics are of great value

for these patients, and comfort and control of the mouth infection are obtained by strict attention to oral hygiene and warm irrigations of saline and sodium bicarbonate. Even within the forward areas, special hospitals may be designated to receive these patients so that the best use may be made of the available personnel.

The Thorax. The chest occupies 16 per cent of the body area whereas wounds of the thoracic region itself account for only about 10 per cent of all wounds. This is in large part attributable to the fact that, like wounds of the head and abdomen, many of them cause immediate death on the battlefield. Penetrating wounds of the thorax present two principal problems: disturbance in the respiratory or cardiorespiratory systems, and infection. The first may be insignificant and hardly noticeable or it may be accompanied by severe hemorrhage and shock and a gaping pneumothorax. Early correction of the disturbed physiology minimizes the dangers of infection later.

Open pneumothorax is treated on the field or at the Aid Station with a snug occlusive dressing which is not disturbed until a suitable hospital is reached. Here, after necessary resuscitation, the wound is débrided and the opening into the thorax closed; the skin is left unsutured. Débridement of a wound of the thorax consists of removal of all damaged tissue and bone fragments, careful hemostasis, complete aspiration of the pleural cavity, and inspection of the intercostal or internal mammary vessels. The lung is expanded, the muscles are closed, and an occlusive dressing is applied. When there is danger of a pressure pneumothorax, a catheter is inserted through the second interspace anteriorly and underwater drainage estabtablished for a few days. In the more severe injuries, tracheostomy may be advisable.

There has been considerable discussion as to the advisability of primary formal thoracotomy at the time of the initial operation. In our experience, however, this is unwise. The only indications for primary thoracotomy, either by extension of the wound or by a new incision at a site of election, are: 1. continuing intrapleural hemorrhage, 2. evidence of injury to the trachea or larger bronchi, 3. evidence of large retained intrapleural foreign bodies, 4. evidence or suspicion of damage to mediastinal viscera, 5. evidence of involvement of the *diaphragm and abdominal* cavity. Unless one of the above indications exists, there is no indication at this time for a formal thoracotomy. Foreign bodies in the lung parenchyma can be removed at some later date with less risk and less chance of empyema.

Postoperatively the chest is aspirated as often as required to keep it dry and encourage re-expansion of the lung, which will also decrease the liability to infection. The problem of foreign bodies in the lung, clotted hemothorax and empyema belong to the reparative phase of surgery in the fixed hospitals of the Communication Zone where there are thoracic centers with surgical and medical specialists skilled in handling these conditions.

The Abdomen. Only about 4 per cent of wounds seen in Army hospitals are abdominal, and another 1 per cent will penetrate both the thorax and abdomen, although the abdomen comprises 11 per cent of the body area. The discrepancy is readily explained. The battlefield mortality of these wounds is high, and also the position of the advancing soldier offers a certain degree of protection to the abdomen. The closer a hospital is to the front, the greater the number of patients with abdominal wounds it will receive and the higher will be the mortality figures. The principal difficulties that confront the surgeon are hemorrhage, severe shock, and infection. The great majority of these patients are properly taken to the MASH units, and a smaller number of the less severely wounded to the Evacuation Hospitals. Because of the impending or established infection, the time lag to initial surgery should be as short as possible. If there is active hemorrhage, resuscitation cannot be complete until this is stopped by operation. Not over two to three hours should be spent in resuscitation; if there is no response to adequate blood replacement therapy, the failure is generally due to continuing hemorrhage, extensive soiling and peritonitis, or massive evisceration.

In the preoperative preparation of these casualties, the stomach should always be emptied. The anesthesia is preferably endo-

tracheal gas-oxygen-ether and a long midline incision is the one of choice. Small intestinal wounds are repaired individually when possible. If the damage is too extensive, however, or the repairs seem likely to cause obstruction, resection and an end-to-end anastomosis is performed. Large intestinal wounds should be exteriorized without tension. If this is not possible, then they should be closed in two layers and a proximal colostomy provided, usually with complete division of the gut, although at times a simple loop colostomy may be sufficient. The colostomy should always be brought out through a separate incision to prevent sepsis in and rupture of the large exploratory incision.

Wounds of the *rectum*, both intraperitoneal and extraperitoneal, and wounds of the anus demand sigmoid colostomy. Drainage of the perirectal space, in extraperitoneal rectal wounds, must also be provided at the time of the original operation by perirectal incisions through the fascia propria into the areolar tissues about the rectum. Removal of the coccyx occasionally may be required to accomplish this. In all wounds of the buttocks and flanks penetrating the abdomen, it is wiser to do the débridement first and the abdominal exploration second as these patients do not tolerate the prone position well after laparotomy.

Wounds of the *solid viscera* are treated according to usual civilian standards. Frequently nothing need be done to the liver if bleeding has ceased. If it has been extensively damaged, however, loose fragments should be gently removed and hemorrhage controlled by suture or a pack inserted with just sufficient pressure to control the bleeding. All liver wounds should be drained to prevent accumulations of the bile within the peritoneum. If the wound of the liver is not packed, the subdiaphragmatic space should be drained and great attention paid to insure a proper repair of the diaphragm. If subdiaphragmatic drainage is not established, the chances are great that there will be a collection of bile with or without perforation into the thorax.

The *kidneys* are treated with great conservatism, and only those irretrievably damaged are removed, but in every instance the opposite kidney should always be palpated. The patients should be carefully followed, however, as the possibility of a functionless, or "dead," kidney, which may necessitate removal at a later date, is real. Suprapubic cystostomy is provided after repair of wounds of the bladder, and if there is urethral damage as well, an indwelling catheter is also maintained in place.

General Considerations in Abdominal Wounds. Transfusion and plasma therapy are continued during the operation and in the postoperative period and careful attention given to the fluid and electrolyte balance. These patients must not be drowned or waterlogged by the overenthusiastic administration of parenteral fluids. If large amounts of blood are required, it is wiser to use identical type blood because of possible renal depression. Since these patients do not stand transportation well, every effort should be made to hold them in the original installation for 10 to 12 days.

An analysis of 55,000 battle casualties received in its forward hospitals as reported by a U.S. Army in the European Theater is given below; the mortality rates are also shown:

TABLE 3.

Classification	Battle Casualties (MASH) Field	Battle Casualties Evacuation	Mortality (%) (MASH) Field	Mortality (%) Evacuation	Mortality (%) Total
Abdominal	1,299—26.0%	906— 1.8%	24.6	11.5	19.2
Thoraco-abdominal	264— 5.3%	187— 0.4%	26.5	15.0	21.7
Thoracic	1,875—33.6%	2,645— 5.3%	8.7	3.3	5.4
Maxillofacial	111— 2.2%	3,211— 6.4%	2.7	0.7	0.8
Head	188— 3.8%	3,163— 6.3%	18.6	8.6	9.1
Spine	49— 1.6%	371— 0.7%	20.4	8.1	9.5
Upper Extremity	285— 5.7%	14,174—28.3%	5.0	0.3	0.5
Lower Extremity	860—17.2%	21,044—42.0%			
Other	266— 5.2%	4,393— 8.8%	8.5	0.7	1.1
Total	5,197	50,094	13.2	1.4	2.5

The higher mortality figures in the Field Hospitals reflect clearly the type of patients these units treated: they were the nontransportables, among whom the mortality is bound to be high. Nor is there the diluent of the many slight wounds in all parts of the body that make up a large part of the work in Evacuation Hospitals.

Hand Injuries. Even at the start of World War II, damaged hands were generally carefully splinted without thought as to future reconstruction; in fact, they were often splinted with traction and full extension or flexion, instead of in the normal relaxed position of function. In dealing with wounds of the hands in forward echelons, several basic principles should be kept in mind. First, the hand should always be loosely immobilized in its natural position of relaxation and function. Second, no tendons or nerves should be sutured. Hands should be carefully débrided and loosely sutured so as to provide for a minimum of scar tissue and as clean healing as possible. At the same time such procedures will cover exposed tendons and nerves. If there has been large loss of substance, an attempt should be made, if feasible, to bury the hand in an abdominal or thigh flap: in other words, try to get the open surfaces and exposed tendons covered with the hand in position of relaxation and ready for transportation to the Base, where true reconstructive surgery may be instituted.

Genital Injuries. As regards the genitals, there is little to add to what has already been said. As to wounds of the *bladder,* these of course must be sutured and suprapubic drainage temporarily established. If the *urethra* is damaged, a temporary splint should be inserted such as a catheter, probably Foley type, and it may be necessary to insert this in a retrograde fashion. If the scrotum has been avulsed and the testes exposed, it is essential that débridement be carefully performed and the skin loosely closed. If there has been loss of substance, the testicle can be readily buried temporarily in the thigh and the remains of the scrotum stitched loosely to the thigh so as to prevent retraction. The patient is now safe for evacuation, and the extravasation of urine has been prevented.

Burns. In World War II, burns presented no major problems in the Army because the incidence was low. They were commonly caused by explosions and fires within tanks during tank warfare, by phosphorous shells or bombs, by bombs and scattering of flaming liquid or incendiary material, by bursting of steam pipes on ships in naval warfare, and by explosions and fires in areoplanes, and by propellants. There are also the many flash burns incident to the extensive use of gasoline by a mobile army. Chief among these are those burns resulting from minor explosions and flares associated with the use of field ranges. The same principles of treatment apply as are practiced in civilian surgery. The initial care consists of a minimal cleansing by gentle means and the application of uniform pressure dressings with the added protection of a plaster cast as indicated for comfort or to assure immobilization. Plasma and transfusion therapy is governed by the estimated extent of the burn, the needs of the patient, and his hemoglobin and hematocrit levels. The strictest asepsis and masking should be practiced whenever the dressings are changed, and granulating areas should be covered with split thickness grafts as soon as the sloughs separate. Patients with extensive or severe burns present the same nursing and feeding problems as they do in civil life; hence, they should be evacuated from the forward hospitals to the base as early as is compatible with their safety. In severe burns of the face and the neck, tracheostomy may be life saving.

In most instances of major burns, closed treatment is indicated. In the event of mass casualties, however, this may not be possible and even those with minor burns would have to aid in the rescue work. Pain in most burns diminishes greatly or ceases within about thirty minutes. Wherever possible, a simple dry dressing should be used. If cleansing is necessary, one of the modern surgical detergents is best employed. These are less irritating, less macerating, and far more efficient than ordinary soap.

When damage to the lungs is suspected, oxygen is needed and the amount of plasma and blood administered should be limited so as not to overload the cardiorespiratory system.

New problems are presented with thermo-

nuclear missiles. In the initial effects, there will be large numbers of burns (40 to 60 per cent) of all degrees of intensity. Many patients will also suffer from the explosive effects of the bomb or from flying or falling objects. In addition to the explosion and the terrific heat generated, there is likewise an enormous amount of radioactivity liberated, which penetrates and extends over a varying distance, and also in the fallout area, so that those in the path of the radioactivity will exhibit effects ranging from alopecia and mild delayed burns to sterility, marked agranulocytosis, blood destruction, and death. With the ordinary high air bursts, except for the initial damage by the liberated radioactivity, there is little added danger from this source inasmuch as the radioactive cloud soon blows away. This condition, however, is quite reversed in ground or water bursts, in which cases the radioactivity persists. There are three general classifications of radiation injury: 1. the very severe; almost all of these patients will die within the first two or three days no matter what is done for them. 2. The moderately severe radiation effect; in these instances radiation illness will appear within several days, although there may be an initial wave of nausea or slight diarrhea; then the signs of anemia and leukopenia will appear with multiple hemorrhages, nausea and bloody diarrhea. Some of these patients will be saved by prompt hospitalization, transfusions and adequate diet and good care. 3. The third group consists of those with minor radiation effect; almost all of these patients will recover. The appearance of the illness will be delayed and their blood counts will show relatively minor damage. The lethal initial dose is in the neighborhood of 600 r whereas in the moderately severe cases the dosage may be between 200 and 400 r.

Cold Injury (21)—Trench Foot. This is the term generally applied to a condition resulting from prolonged exposure of the feet to cold and moisture, usually, though not necessarily, associated with dependency and immobility and with constriction of the limbs by shoes and other clothing. It is closely related, though not precisely similar, to immersion foot and shelter foot.

Important factors in the development of trench foot are:

1. Temperature. The incidence increases as the temperature drops below 55° F.
2. Length of exposure. This may vary from hours to weeks.
3. Dependency and immobility. Men who sit or stand in trenches and who crouch in foxholes for long periods of time are particularly likely to develop trench foot.
4. General chilling. This results in general vasoconstriction and circulatory stagnation.
5. Footwear. Constricting footwear, and that which does not afford adequate warmth and protection or does not permit evaporation, predispose to trench foot, although keeping the feet dry is considerably more important than is the factor of evaporation.
6. Age. Men under 17 and over 40 years of age are more susceptible to trench foot than those within these age limits.
7. Previous environment. The experience of the Hawaiian-Nisei groups in the Mediterranean and European Theaters in World War II suggests that individuals accustomed to a warm climate have a lower resistance to the combination of cold and wet environments than do those accustomed to colder climates.
8. Trauma.
9. General nutritional deficiency.
10. A history of previous trench foot of moderate severity, or peripheral vascular disease.

Pathology. During the period of exposure and hypothermia, there is peripheral vasoconstriction, chiefly of the arterioles but sometimes also of larger arteries. The resultant ischemia causes anoxia, which results in increased permeability of the capillaries, exudation, and edema. These changes may be accentuated by existing arterial disease, tight shoes or leggings, prolonged exposure to cold, and trauma incurred from walking on the damaged feet.

Immediately after exposure to warmth, a marked inflammatory hyperemia of the part occurs with excessive vasodilation. This is accompanied by swelling and edema, which, though due chiefly to increased permeability of the damaged capillaries, are caused in part, also, by mechanical factors. Thus a vicious circle is established, in which transudation increases the already existing oxygen deficiency. There may likewise be peripheral nerve changes as evidenced by the paresthe-

sias, anesthesias, and sudomotor disturbances present.

CLINICAL MANIFESTATIONS. The clinical manifestations vary, and depending upon the length of exposure and degree of tissue damage, the lesions may be classified as mild, moderate, or severe. The mild type exhibits erythema, slight tingling or paresthesias, and little edema, if any. In the moderate cases there are pitting edema, blebs, and ecchymosis. In the severe form the symptoms and signs are accentuated, with bullae, extravasations of blood, and incipient or actual gangrene.

The earliest symptoms consist of coldness and numbness of the feet and sometimes tingling or aching. The most prominent symptoms, however, are numbness and a heavy wooden feeling. Walking is clumsy, as if "on blocks of wood." If the shoes are removed, the feet will be found to be cold and partially anesthetic to pain, touch, and temperature. Swelling usually is not marked and the skin, at first red, soon becomes white, waxen, or mottled blue. Later, blisters appear. Frequently at this stage, when the shoes are removed for the purpose of resting, drying, or rubbing the feet, the patient discovers that he is unable to put them on again because of swelling.

After several hours as the symptoms progress, there will be increased swelling, mottling, and areas of anesthesia, most commonly about the toes, plantar, and lateral aspects of the feet. At first the peripheral pulses may be absent. As the feet grow warm, swelling increases rapidly and a severe burning pain begins; this marks the beginning of the second or hyperemic stage.

This stage may persist for days or weeks and the feet become hot, red, and dry and the pulses full and bounding. Blebs and patchy ecchymosis appear, with the damage greatest about the toes and distal part of the foot. Actual gangrene may be present in severe cases. The anesthesia is replaced by paresthesias and an intense burning pain relieved by cold and made worse by heat. The affected parts may ache and throb, there are scattered areas of hyperesthesia and paresthesia, and there is anhydrosis. In severe cases, the edema may extend all the way to the knees. After four to six days, all the symptoms begin to subside. If the injury has not been great, the skin assumes a normal color after some exfoliation. Occasionally, however, the feet become cold, blue, and sweaty. The usual complications are phlebothrombosis and infection, localized or spreading. Rarely, transient hematuria and albuminuria, enlargement of the liver, and mild fever may be noted.

In the posthyperemic stage, the condition apparently progresses to complete recovery in the milder cases. Symptoms may persist for a long time, however, in the most severe forms, and are aggravated by walking, standing, or exposure to cold. Deep-seated pain, stiffness in the joints, and osteoporosis may persist, and there may be a residual hyperhydrosis of the feet and an excessive sensitivity to cold.

PREVENTION. Prophylactic measures consist, first, in the provision of adequate warm and protective footwear and clothing and the avoidance of unnecessarily prolonged exposure; and, second, in a campaign of instruction to officers and men in the prevention of trench foot. The formulation of the prophylactic routine is the responsibility of the surgeon, but its implementation is the responsibility of the military command itself. *Unit commanders must be interested in and assume responsibility for the care of the feet of their troops.* The incidence of trench foot will rise or fall in direct ratio to the cooperation of all elements of the command.

Measures of Major Importance. 1. Loose-fitting waterproof or water-resistant boots are essential. They should be equipped with removable inner soles and should be large enough to accommodate two pairs of woolen socks (one light and one heavy) so as to provide sufficient insulation, ventilation, and absorption. The insulated type boot and the shoe-pac with rubber foot piece and leather top seem to be the best type of footgear except on rough or mountainous terrain. Troops must be instructed *not* to lace the boots tightly.

2. Proper clothing and gloves should be worn. They should be wind and water resistant and of good insulating properties. Constriction by all clothing, particularly leggings, socks, and garters, must be avoided.

3. An abundant high-caloric, high protein diet should be provided; whiskey and

other alcoholic beverages are to be avoided.

4. Every effort should be made to keep the feet dry. A compulsory daily sock exchange may be arranged, to be operated by the company mess section, and drying shelters and tents can be provided.

5. Prolonged immobility should be avoided.

6. The boots should be removed at least once daily, the feet dried and massaged, dry socks put on, and inner soles replaced. Under good foot discipline, men are assigned in pairs, each one being responsible for the daily care of the other's feet.

7. Weekly foot inspections should be held.

8. Whenever it is at all possible, there should be frequent relief of front line units in cold weather.

The incidence of trench foot can be sharply reduced by such a program, but no matter what is done nor how good the foot discipline in any unit, when that unit goes into the line in cold, wet weather, its trench foot curve will rise, such rise depending upon the feasibility of carrying out the above measures.

TREATMENT. Treatment consists of rest, elevation of the feet, prevention of infection, and ambulation as early as possible.

Initially the patient should not be permitted to walk. His wet clothes should be removed and his feet gently cleansed with white soap and water and then thoroughly dried. He should be kept warm, but his feet should be left exposed to the air and elevated on pillows, with especial care to avoid pressure on the heels.

Cooling at room temperature is usually adequate provided the temperature does not exceed 70° F. If ice bags are used, the foot must be well protected by pledgets of cotton between the toes and sterile cotton batting wrapped around the foot so as to protect the tissues.

In the early prehyperemic stage, when vasospasm is still present, whiskey may be given. Sympathetic block is seldom indicated, as its effect is too prolonged and the pain of the hyperemic stage is aggravated.

Massage is contraindicated in the prehyperemic and hyperemic stages.

Measures to prevent infection, including tetanus, should always be instituted. Blebs are ordinarily left alone, but if they are to be opened it should be done with a sterile needle under aseptic precautions. Areas of necrosis and gangrene are treated conservatively and amputation should be delayed as long as possible, for generally the actual tissue destruction is not as great as would appear, even after careful examination.

After the edema and hyperemia have subsided, graduated vascular exercises, gentle massage, warm baths, and passive movements should be started, and the patient then allowed out of bed after a week.

If intractable pain and edema persist, compression dressings or elastic bandages may be cautiously employed and sympathetic block may be tried. Lumbar sympathectomy is indicated only when test blocks have given relief or when manifestations resembling Raynaud's disease develop and persist.

Frostbite. The injury in frostbite is not dissimilar to that of trench foot with ischemia, vascoconstriction and sludging of the blood in the capillaries. Unless the circulation can be re-established, there will be destruction of the skin and deeper tissues proportionate to the duration and extent of the injury. The treatment consists in moderately rapid warming by gentle massage or rubbing with alcohol if the tissues are intact. The temperature of the room should be in the nature of 65° to 70° F. and the injured member slightly depressed. A small infusion of alcohol and novocain is given at once to bring about a vasodilatation. Not more than one sympathetic block is indicated to assure abolition of all vascular spasm. Treatment then consists of protection of the damaged part from infection, a rather cool temperature, and the institution of anticoagulant therapy. Even though the injury may be 48 hours old, anticoagulants may still be of value; heparin may help relieve the pain, and in addition the area of gangrene and final loss of tissue may be lessened by their use. The anticoagulants need not be used to the same extent as in the treatment of venous or arterial thrombosis, and a safe level should always be maintained. Amputation should be avoided as long as possible as in many in-

stances what appear to be irretrievably damaged parts will recover with proper expectant treatment.

CHEMICAL WARFARE (22)

The scope of chemical warfare is broad because it aims at whole groups of people and large areas of terrain rather than at individuals. It may be used to start fires, to make land untenable and water undrinkable, to produce casualties, and for purposes of concealment.

Agents. Chemical warfare agents may be classified according to their physiologic action, their persistence, and their tactical use:

(a) *Physiologic Action.*

1. Lung irritants, whose primary damage is to the respiratory tract
2. Vesicants, which injure the eyes, produce erythema and blisters on the skin, and damage the respiratory tract when inhaled: mustard, lewisite
3. Lacrimators or tear gases, which act primarily upon the eyes, causing tears and temporary pain
4. Irritant smokes or sternutators (vomiting gases), which irritate the eyes and throat and cause temporary prostration
5. Systemic poisons, which stop essential physiological processes: nerve gases

(b) *Persistence.* Persistence varies greatly. Mustard is an example of a persistent agent and phosgene is nonpersistent.

(c) *Tactical Use.*

1. Agents that injure or kill personnel—mustard, nerve gases
2. Harassing agents, to force the wearing of masks and to impede operations—irritant smokes
3. Screening agents to produce dense smoke—white phosphorous
4. Incendiaries

From the standpoint of actual warfare, the two most important groups of these chemical agents in the production of casualties are the nerve and mustard gases, against both of which gas masks are effective. It is extremely difficult to detect nerve gas, however, and its action is exceedingly rapid, with very high mortality. The only remedies we have against it at the present time are large doses of atropine and oxygen administration. The atropine should be repeated after five minutes if no relief is obtained. Nerve gas attack can decimate large areas with great rapidity.

The nerve gases act on the respiratory center by interfering with the metabolism of acetyl choline so that this substance accumulates and the formation of cholinesterase is inhibited. This results in respiratory paralysis. The treatment is immediate hospitalization, oxygen therapy, and large doses of intravenous atropine, which should be repeated at intervals until the respiratory mechanism is well established.

The mustard group includes mustard, nitrogen mustard, lewisite and some others. The effects of these are primarily upon the eyes and the skin; when inhaled there is damage to the respiratory tract; and when they are absorbed they cause systemic poisoning. The eyes may be permanently affected. Persons contaminated with the vesicants endanger those who come in contact with them, and both they and everything they touch must be decontaminated. Those in contact with these casualties should wear protective masks and impermeable gloves and aprons, or protective clothing if the area is contaminated. The agents persist from hours to days, particularly in cold, damp weather and in dark, poorly ventilated places. The best treatment for any of these gases is thorough washing with soap and water and irrigation of the eyes with water or 3 per cent sodium sulamyd solution, which should be instilled every four to eight hours and sterile petrolatum applied to the lids. The eyes must not be bandaged. For nitrogen mustard and lewisite, BAL solution and ointment should be used early. Although extremely irritating to the normal skin and eyes, they give prompt relief to the blepharospasm, erythema, and blisters caused by the lewisite. The lesions caused by these gases require weeks to heal; thus these agents are ideal for the purpose of disabling large masses of people, who in turn will require others to care for them.

Biological Warfare. Biological warfare presents itself in several phases: 1. bacteria in bombs or aerosol mists, 2. viruses, 3. food poisonings and toxins such as botulinus, 4. destruction of crops by spraying or implantation of disease molds or organisms, 5. epizootics and zoonoses by any of the above methods. From the standpoint of this résu-

mé, it is necessary only that one should be aware of the manifold methods in which this type of warfare can be waged. Biological warfare is of special interest to preventive and veterinary medicine and sanitary engineering. Like chemical warfare, it destroys neither the land nor the buildings as opposed to thermonuclear warfare. It may produce large numbers of casualties, with mortality varying with the agents used. Along with the casualties produced, it spreads panic and fear, and by its employment many of those who are unaffected will be required to care for the sick and also to till the soil so as to provide sufficient food in the event that biological agents are employed to destroy crops and dairy and food animals.

SURVIVAL OR DISASTER MEDICINE AND SURGERY

With our present weapons development offense has outrun defense for the time being, so that one country may deliver a massive attack upon another country, with resulting casualties of unimaginable numbers. The 300,000 wounded of the British Army in the Battle of the Somme in World War I over a period of two and a half to three months are infinitesimal in numbers compared to the casualties that would result from a single major sneak attack from the air or a combination of air and sea. Not only can such an attack result in millions of casualties occurring practically simultaneously, but at the same time there would be complete disruption of communications, food and water supplies, sanitation, and the whole economy of a nation. Following such attack, great conflagrations would occur, and there would probably be a heavy and extensive fallout pattern, to say nothing of the area itself, which might well be grossly contaminated with radioactive materials for a period of 10 to 14 days.

The transition from normal economy to one of national survival will occur within a few short moments. How can we plan to meet such a terrifying situation? To assume as many do today that, "It can't happen here" is false; rather, we know it can happen but we HOPE it will not. Nevertheless, there must be some sort of preparation.

Three departments of government* immediately assume paramount importance:

1. Office of Defense Mobilization
2. Department of Defense
3. Federal Civil Defense Administration

To show the function of this structure, the Office of Defense Mobilization would probably become the over-all governing agency for the apportionment of total resources, both human and material. Defense and Federal Civil Defense Administration would both be claimants to it. First, even before assessment of any damage, however, the needs of the sick and wounded present themselves immediately and medical care must be ready. With only slight delay, preventive medicine and sanitation come to the fore in order to minimize to as great an extent as possible the spread of epidemics. New disease patterns may arise, such as the appearance of hemorrhagic fever in Korea, dysentery, influenza, other infectious diseases, possibly even plague, zoonoses, and also starvation.

Quite apart from the federal groups concerned, each community must have its own medical organization in order. Studies have shown that about one-third of the major medical facilities are located in primary target areas and about 80 per cent of the medical, dental, nursing, and ancillary medical personnel are located in our large metropolitan centers. In other words, the ratio of casualties between (A) the medical and allied groups as compared to (B) the rest of the population would probably be about sixty to forty (A:B). Therefore, there will be an extreme shortage both of personnel and of facilities, and "hundreds of thousands of casualties who under normal circumstances would recover, will die due to the lack of trained personnel, adequate facilities and necessary supplies."

* Since the writing of this chapter the Office of Defense Mobilization and the Federal Civil Defense Administration have been combined into a single office, the Office of Civil and Defense Mobilization. Thus, this office now consists of two parts. It has become the over-all governing body but within it there is the suboffice of civil defense. This suboffice of civil defense administration and the Department of Defense would both become claimants in time of great emergency for apportionment of resources personnel, production, material, transportation, communications, food, medical facilities, and so forth.

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4. Irritant smokes or sternutators (vomiting gases), which irritate the eyes and throat and cause temporary prostration
5. Systemic poisons, which stop essential physiological processes: nerve gases

(b) *Persistence.* Persistence varies greatly. Mustard is an example of a persistent agent and phosgene is nonpersistent.

(c) *Tactical Use.*

1. Agents that injure or kill personnel—mustard, nerve gases
2. Harassing agents, to force the wearing of masks and to impede operations—irritant smokes
3. Screening agents to produce dense smoke—white phosphorous
4. Incendiaries

From the standpoint of actual warfare, the two most important groups of these chemical agents in the production of casualties are the nerve and mustard gases, against both of which gas masks are effective. It is extremely difficult to detect nerve gas, however, and its action is exceedingly rapid, with very high mortality. The only remedies we have against it at the present time are large doses of atropine and oxygen administration. The atropine should be repeated after five minutes if no relief is obtained. Nerve gas attack can decimate large areas with great rapidity.

The nerve gases act on the respiratory center by interfering with the metabolism of acetyl choline so that this substance accumulates and the formation of cholinesterase is inhibited. This results in respiratory paralysis. The treatment is immediate hospitalization, oxygen therapy, and large doses of intravenous atropine, which should be repeated at intervals until the respiratory mechanism is well established.

The mustard group includes mustard, nitrogen mustard, lewisite and some others. The effects of these are primarily upon the eyes and the skin; when inhaled there is damage to the respiratory tract; and when they are absorbed they cause systemic poisoning. The eyes may be permanently affected. Persons contaminated with the vesicants endanger those who come in contact with them, and both they and everything they touch must be decontaminated. Those in contact with these casualties should wear protective masks and impermeable gloves and aprons, or protective clothing if the area is contaminated. The agents persist from hours to days, particularly in cold, damp weather and in dark, poorly ventilated places. The best treatment for any of these gases is thorough washing with soap and water and irrigation of the eyes with water or 3 per cent sodium sulamyd solution, which should be instilled every four to eight hours and sterile petrolatum applied to the lids. The eyes must not be bandaged. For nitrogen mustard and lewisite, BAL solution and ointment should be used early. Although extremely irritating to the normal skin and eyes, they give prompt relief to the blepharospasm, erythema, and blisters caused by the lewisite. The lesions caused by these gases require weeks to heal; thus these agents are ideal for the purpose of disabling large masses of people, who in turn will require others to care for them.

Biological Warfare. Biological warfare presents itself in several phases: 1. bacteria in bombs or aerosol mists, 2. viruses, 3. food poisonings and toxins such as botulinus, 4. destruction of crops by spraying or implantation of disease molds or organisms, 5. epizootics and zoonoses by any of the above methods. From the standpoint of this résu-

mé, it is necessary only that one should be aware of the manifold methods in which this type of warfare can be waged. Biological warfare is of special interest to preventive and veterinary medicine and sanitary engineering. Like chemical warfare, it destroys neither the land nor the buildings as opposed to thermonuclear warfare. It may produce large numbers of casualties, with mortality varying with the agents used. Along with the casualties produced, it spreads panic and fear, and by its employment many of those who are unaffected will be required to care for the sick and also to till the soil so as to provide sufficient food in the event that biological agents are employed to destroy crops and dairy and food animals.

SURVIVAL OR DISASTER MEDICINE AND SURGERY

With our present weapons development offense has outrun defense for the time being, so that one country may deliver a massive attack upon another country, with resulting casualties of unimaginable numbers. The 300,000 wounded of the British Army in the Battle of the Somme in World War I over a period of two and a half to three months are infinitesimal in numbers compared to the casualties that would result from a single major sneak attack from the air or a combination of air and sea. Not only can such an attack result in millions of casualties occurring practically simultaneously, but at the same time there would be complete disruption of communications, food and water supplies, sanitation, and the whole economy of a nation. Following such attack, great conflagrations would occur, and there would probably be a heavy and extensive fallout pattern, to say nothing of the area itself, which might well be grossly contaminated with radioactive materials for a period of 10 to 14 days.

The transition from normal economy to one of national survival will occur within a few short moments. How can we plan to meet such a terrifying situation? To assume as many do today that, "It can't happen here" is false; rather, we know it can happen but we HOPE it will not. Nevertheless, there must be some sort of preparation.

Three departments of government* immediately assume paramount importance:

1. Office of Defense Mobilization
2. Department of Defense
3. Federal Civil Defense Administration

To show the function of this structure, the Office of Defense Mobilization would probably become the over-all governing agency for the apportionment of total resources, both human and material. Defense and Federal Civil Defense Administration would both be claimants to it. First, even before assessment of any damage, however, the needs of the sick and wounded present themselves immediately and medical care must be ready. With only slight delay, preventive medicine and sanitation come to the fore in order to minimize to as great an extent as possible the spread of epidemics. New disease patterns may arise, such as the appearance of hemorrhagic fever in Korea, dysentery, influenza, other infectious diseases, possibly even plague, zoonoses, and also starvation.

Quite apart from the federal groups concerned, each community must have its own medical organization in order. Studies have shown that about one-third of the major medical facilities are located in primary target areas and about 80 per cent of the medical, dental, nursing, and ancillary medical personnel are located in our large metropolitan centers. In other words, the ratio of casualties between (A) the medical and allied groups as compared to (B) the rest of the population would probably be about sixty to forty (A:B). Therefore, there will be an extreme shortage both of personnel and of facilities, and "hundreds of thousands of casualties who under normal circumstances would recover, will die due to the lack of trained personnel, adequate facilities and necessary supplies."

* Since the writing of this chapter the Office of Defense Mobilization and the Federal Civil Defense Administration have been combined into a single office, the Office of Civil and Defense Mobilization. Thus, this office now consists of two parts. It has become the over-all governing body but within it there is the suboffice of civil defense. This suboffice of civil defense administration and the Department of Defense would both become claimants in time of great emergency for apportionment of resources. personnel, production, material, transportation, communications, food, medical facilities, and so forth.

The problem of sanitation has been previously mentioned; one must also consider the problem of disposal of the dead. The Federal Civil Defense Administration will provide small hospitals and stockpile short lists of essential medical items. Limited emergency lists of medical items have already been accumulated by the Department of Defense, and work is progressing with somewhat encouraging results on preservation of whole blood or red cells for long periods of time. This could be stored in many places. The patterns of medical care and of medical materiel storage should be just the reverse of that which we follow in our peacetime economy. All of this storage of materiel should occur at points well dispersed from the major centers so that should such disaster ever occur, the problem will be not that of trying to salvage what might be left from the mountains of debris, but rather that of moving the much needed personnel and supplies from the periphery toward the damaged areas. Simultaneously the survivors in these areas with their own organization would be moving toward and establishing their treatment centers in the periphery or undamaged territory. There should be a neighborhood or block-type organization with neighbor taught to help neighbor and in addition, if confusion is to be prevented, there must be a system of local predesignated leadership established.

It is useless to talk about creating burn centers or any other kind of centers within our large metropolitan areas to care for casualties in such major disaster. These areas themselves will be destroyed. Our large metropolitan and industrial zones should therefore look to their periphery 50 to 60 miles away, where there should be previous stockpiling of materiel for assistance in case of such need.

Instead of assuming a defeatist attitude, the sensible way of regarding such an overwhelming catastrophe is to look upon it in three phases.

1. "*Survival.*" Aside from the immediate care of the wounded and dead, the major problem will be that of transport of food and water to prevent starvation, and, next, sanitation and preventive medicine to prevent and control epidemics. By these measures the ground work is laid for the resumption of industry and communication. During this period, both military and civilian would have to interdigitate very closely. Little effective support for the military could be provided from the civilian economy, and the armed forces would have to make maximum use of most of their own available resources to carry out their own mission and to prepare for phase two.

2. Depending upon the speed with which this can be accomplished, the second phase might be called "*Defensive-offensive.*" During this period, recovery and rehabilitation are underway and supplies may be reaccumulated. The lesser ill and wounded are now active again and our economy is recovering.

3. The third phase is "*Offensive.*" Now we are beginning to gather strength and reserves and can move forward once more.

Just as the area of the field of battle itself back to the Battalion Aid Station is of extreme importance in the saving of human life, the same will be true in the initial survival period. And how well and rapidly that survival is accomplished will depend upon our realization of the need of dependence on suburban and rural areas for human reserves and materiel supplies and their organization, stockpiling, and utilization. If one assumes the attitude that "It can't happen here" and relies upon the large centers, as we customarily do in peace, then we may well find that our house was built upon the sand, and it will fall.

GLOSSARY OF TERMS

A FIELD ARMY is the largest combat unit operating in the field.

COMBAT ZONE: The immediate area of combat. This area varies in depth and extent. It is directly under the control of the Field Army commander.

ZONE OF COMMUNICATIONS: This varies with the type of warfare and the area of battle. It extends from the rear of the Combat Zone to the points of debarkation in the United States.

ZONE OF INTERIOR: The boundaries of the United States.

BATTALION AID STATION: The first medical installation to which a wounded soldier or Marine is carried from the field of battle. This is a small sheltered area, manned by two Medical Officers, a Medical Service Corps Officer, and a small group of Medical Corps enlisted men.

COLLECTING STATION: A small station usually one to three miles to the rear of the Battalion Aid Station. Ambulances and helicopters are available here. Although this is a useful unit, it may frequently be bypassed or in certain instances temporarily eliminated and used to reinforce other units.

CLEARING STATION: This is the rearmost of the intrinsic medical installations of the division. It is usually five to seven miles behind the forward lines and has a small holding unit. Its primary function in active warfare is a triage center.

MOBILE ARMY SURGICAL HOSPITAL (MASH): A small unit of 50 or 60 beds. This should be within easy access, preferably hand carry distance of the Clearing Station, where all patients who cannot be evacuated further without danger to life are sent from the Clearing Station. This unit is reinforced by expert resuscitation and surgical teams and is equipped for major surgery. In World War II, small units or platoons of the field hospitals operated at this site. These have now been replaced by the MASH Unit.

EVACUATION HOSPITAL (EH): This is the major hospital of the Field Army. It may be a 400-bed unit or larger. All types of medicine and surgery are practiced here, with specialists on the intrinsic staff or reinforced by teams of specialists. These were usually allocated on the basis of one 400-bed EH to a division in World War II. Each two divisions and their 400-bed evacuation hospitals were further supported by one 750-bed EH.

THE AMBULANCE COMPANY: A company of ambulances. These are under the control of the Army Surgeon and temporarily attached to a Corps, or they are held under a Medical Group. They are always in contact with the collecting stations, clearing stations, and hospitals to which they evacuate.

THE MEDICAL GROUP: An independent organization, one of which operates with each Army, is assigned to a Field Army and directly under the command of the Army Surgeon. They assist him and reinforce the Army Headquarters and Corps staffs.

MEDICAL REGIMENT (BATTALION): This unit consists of an Administrative Headquarters and medical officers and troops. It is assigned to the Army. The Administrative Officers take care of their own administration and may assist the Field Army Surgeon as he desires. The medical officers, troops, and ambulances are at the disposal of the Army Surgeon in any manner as he may direct.

EMERGENCY MEDICAL TAG (EMT): A tag applied to each soldier, wounded or ill, either on the field of battle by the Emergency aidman or in the Battalion Aid Station. This accompanies him back to the MASH Unit or Evacuation Hospital where his field record is established from the information contained on the EMT and further history obtained from the patient.

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MEDICAL ETHICS AND CONDUCT

Unethical Practices
Relationship of Physician to Physician
Relationship of Physician to the Patient
Responsibility to the Community
Malpractice and Medicolegal Aspects of Practice
Euthanasia
Relationship of Physician to Hospital

Physicians practicing medicine, regardless of their specialty, have a responsibility and an obligation to society for their conduct. Greater emphasis on conduct and ethics is perhaps necessary in surgery. Large fees for operation throw temptation into the path of the surgeon. Fee splitting is one of the major errors of conduct confronting the profession. The physician must maintain proper relationships with his colleagues, his patients, his hospital, and the community in which he practices. Problems of conduct and ethics will be discussed in detail after considering some of the historical aspects of medicine.

The Heritage of Medicine. Hippocrates said, "Medicine is of all the arts the most noble." We must appreciate that the medical profession is an altruistic one in which the physician is dedicated to service. Any student who enters medicine with the idea of making a fortune has chosen the wrong profession; while it may be possible to reach this objective, it is better that he change to another field of endeavor where financial gain may be greater. The true rewards of medicine lie in other directions and will be achieved only when our conduct, responsibilities, obligations, and ethics are fully understood. These will be discussed in this chapter. The business aspects of medicine are the subject of the splendid monograph by Truman (1). Details of medicolegal problems are ably discussed by Regan (2a) and by Long, in his recent book (2).

The physician receives his medical degree in a ceremony, during which he pledges himself to the following Oath of Hippocrates:

I swear by Apollo the physician, by Aesculapius, Hygeia, and Panacea, and I take to witness all the gods, all the goddesses, to keep according to my ability and my judgment the following Oath:

To consider dear to me as my parents him who taught me this art; to live in common with him and if necessary to share my goods with him; to look upon his children as my own brothers, to teach them this art if they so desire without fee or written promise; to impart to my sons and the sons of the master who taught me and the disciples who have enrolled themselves and have agreed to the rules of the profession, but to these alone, the precepts and the instruction. I will prescribe regimen for the good of my patients according to my ability and my judgment and never do harm to anyone. To please no one will I prescribe a deadly drug, nor give advice which may cause his death. Nor will I give a woman a pessary to procure abortion. But I will preserve the purity of my life and my art. I will not cut for stone, even for patients in whom the disease is manifest; I will leave this operation to be performed by practitioners (specialists in this art). In every house where I come I will enter only for the good of my patients, keeping myself far from all intentional ill-doing and all seduction, and especially from the pleasures of love with women or with men, be they free or slaves. All that may come to my knowledge in the exercise of my profession or outside of my profession or in daily commerce with men, which ought not be spread abroad, I will keep secret and will never reveal. If I keep this oath faithfully, may I enjoy my life and practice my art, respected by all men and in all times; but if I swerve from it or violate, may the reverse be my lot.

Although Hippocrates (460 to 370 B.C.) may be known as the father of medicine and

of medical ethics and conduct, the same feeling of honor and responsibility to the patient existed before his time. For example, in Babylon, a pride and sense of responsibility was expressed by the Code of Hammurabi (3, 4), dated about 1900 B.C., as follows:

> Concerning the wounds resulting from operations it is written: If a physician shall produce on anyone a severe wound with a bronze operating knife and cure him, or if he shall open an abscess with the operating knife and preserve the eye of the patient, he usually shall receive 10 shekels of silver; if it is a slave, his master shall usually pay two shekels of silver to the physician.
>
> If a physician shall make a severe wound with an operating knife and kill him, or shall open an abscess with an operating knife and destroy the eye, his hands shall be cut off.
>
> If a physician shall make a severe wound with a bronze operating knife on the slave of a free man and kill him, he shall replace the slave with another slave. If he shall open an abscess with a bronze operating knife and destroy the eye, he shall pay the half of the value of the slave.
>
> If a physician shall cure a diseased bone or a diseased organ, he shall receive five shekels of silver; if it is a matter of a freed slave, he shall pay three shekels of silver but if a slave, then the master of the slave shall give to the physician two shekels of silver.

Our scientific debt to our predecessors is great. This has been expressed so well by Barrett (5) that we quote directly from him: "A physician's debt to medicine can never be repaid in full. From the obscure country practitioner to the most renowned surgeon at the great medical center, each has received more from this, the oldest and noblest of professions, than the longest life can repay. From those who have received much, much is expected." The physician has been given much, a great part of which is the vast store of information which has been developed by his predecessors. In turn each of us has a duty to contribute to the great wealth of medical knowledge as well as to fulfill the obligation "to study and treat the ills of mankind, real and imagined, great and small" (5).

All of us know that tuition pays but a small part of the cost of medical education; each physician is financially indebted to society for the additional contribution made to his intellectual development. The physician partially repays society by his care of his patients. He devotes his ability and training to the solution of his patient's problem. Nobility of character develops during the process of serving mankind. The vast majority of our profession have conducted their lives so honorably as to justify the trust placed in them. For this reason the profession has risen to a high position of honor in contributing to the welfare of the people. We must see to it that this trust is not betrayed by the few who might be tempted to do so.

Whatever the field chosen by the young physician, he must realize that there is a need for continuing his education for the rest of his life. In the first place, this means a fundamental education in liberal arts. Too many physicians indeed are unable to write clear, readable papers or speak simply and understandably or even without obvious errors. Continued training can be achieved by many means, including attendance at medical meetings and graduate courses, reading medical books and journals, and personal contacts with other physicians. If the physician does not keep abreast of his field he rapidly becomes out-of-date, and his value to his patient lessens.

Physician's Fees. The young physician may have considerable difficulty in determining the size of his fees for services rendered. There are no rules for making a decision as to the amount of fees. In general, the amount is related to ability to pay, but this is by no means the only determining factor. Important also in determining the fee are the magnitude of the operation and the experience and judgment required on the part of the surgeon. Thus, the fee for an appendectomy should be less than that for a total gastrectomy for cancer even though both are celiotomies.

Regardless of the amount of the bill, the surgeon in most cases should discuss the matter with the patient before the operation, especially on request. This will eliminate much misunderstanding later. If more than one physician has been treating the patient, each should *send his own bill*, in proportion to the service rendered. Any method of fee-splitting is illegal and is condemned by the "Principles of Medical Ethics of the American Medical Association" (6), as discussed in detail under the next heading. If the patient

requests a combined, itemized bill, or there is some other legitimate reason why bills must be combined, each physician should send a receipt to the patient for the amount he receives. However, an exception is made in the formally organized clinics, where the physicians band together on a partnership basis even though each may receive a set salary or percentage of the total net income. Under such circumstances, it is entirely ethical to send a single bill, because the money collected is being distributed by the physicians themselves according to prearranged plan. As Hawley (7) remarks, this is not fee-splitting because there is no element of inducement. The method of payment by insurance companies for medical services rendered is irregular, and the recommendations of many companies are actually unethical, because they will pay only one physician even though two or more physicians may have treated the patient. This method of payment requires either a split of the fee or lack of payment to one of them. The American College of Surgeons is making a strenuous effort at the present time to have the insurance companies correct this error.

The ethics of paying surgical assistants has aroused some controversy. In any major operation, a first assistant is required who, of course, deserves to be paid, unless he is a resident or other full time physician. If a resident is not available, the surgeon must have another assistant; if he is not the referring physician, he may be paid by the surgeon, without discussing it with the patient. It is not ethical to employ the referring physician as assistant if residents are available, or if an assistant more skilled than the referring physician, is available. If there are several surgeons in a clinic, one should be designated as first assistant. In other words, the assistant's fee must not be used as an inducement for referral of the patient, nor fee-splitting disguised as an assistant's fee.

UNETHICAL PRACTICES

Numerous types of unethical practices exist in medicine. The profession must exert all possible effort to abolish them.

Fee Splitting. This is the most common of all unethical practices. It has been defined by the American College of Surgeons as

> the refunding of any portion of the total fee for the care of a patient to either the surgeon or referring physician. Moreover, when the surgeon or the referring physician submits a joint bill, itemized or unitemized, it shall be interpreted as fee-splitting, according to the principles stated by the Judicial Council, and approved by the House of Delegates of the A.M.A., in December 1952.

Rebates, or commissions from manufacturers, pharmacists, chemical companies, laboratories, ambulance companies, and x-ray laboratories are considered unethical. In eleven states, laws have been passed making fee-splitting a crime. In four states fee-splitting has been defined as any division of a fee even though the patient has knowledge of the division. In six states it has been defined as the secret division of a fee.

HARMFUL EFFECTS OF FEE-SPLITTING. Most of the ill effects of this practice are sustained by the patient. It actually is the factor responsible for many other types of unethical practices mentioned below; some are discussed later in more detail.

1. Fee-splitting results in overcharging; the patient actually pays for the act of being transferred from one physician to another.
2. It encourages unnecessary operations. Records show that in localities where fee-splitting takes place, the number of normal organs needlessly removed is high.
3. It results in immoral practice. The patient is used as a pawn, and the physician encouraged to place emphasis on his financial return, not the welfare of the patient.
4. Well-trained, honest young surgeons have difficulty starting practice in a community where fee-splitting is practiced. Patients are not referred to the young surgeon, despite his competence, because he does not split fees; the surgical patients will be sent to other surgeons who may or may not be competent but who offer the highest rebate.

MEANS OF PREVENTING OR ELIMINATING FEE-SPLITTING. Numerous means are available for correction of this evil, even though it is difficult to detect, since usually only two parties are involved in the practice. Some methods of prevention are enumerated below:

1. The surgeon should emphasize the importance of team work by telling the patient the importance of the initial care and establishment of the diagnosis by the referring physician.

2. The public should also be educated as to the value of the services of the referring physician and the justification of a fair fee for him.

3. The medical profession should publicly condemn excessive fees.

4. The medical societies, hospital staffs, and faculties of medical schools should impress upon students and medical trainees the evils of fee-splitting.

5. Medical societies should establish a method of punishment for fee-splitting, whether it be cancellation of membership or some other punitive measure.

6. Medical societies should establish Grievance Committees to which lay people as well as physicians may go for discussion of financial or other complaints. All physicians should be educated to the philosophy that fee-splitting is a serious evil.

7. Fees should be adapted to the patient's ability to pay. The surgeon should consult more freely with the patient or referring physician regarding the size of his fee in relation to the patient's ability to pay.

8. All physicians should be educated to tell the patient where the total professional fee goes, except in organized clinics, where such explanation is not necessary even though it is usually made.

9. If a hospital is having difficulty with ghost surgery, the patient may be required to sign an operative permit with the name of the operating surgeon thereon.

10. The hospital may ask all staff members to submit their financial books to an accountant.

11. Tissue Committees will minimize or eliminate needless surgery, and in this way will counteract fee-splitting.

Ghost Surgery. This term "is applied to an operation in which the patient is not informed of, or is misled as to the identity of the operating surgeon" (7). Under such circumstances the family physician permits the patient to believe that he is going to perform the operation, but instead employs another physician to do the operation without the patient's knowledge. The "ghost" surgeon usually does not meet the patient, but performs the operation and does not visit the patient postoperatively. He accepts the diagnosis without examining the patient and is told where to cut (8). The family physician collects the fee from the patient and splits it with the surgeon who performed the operation. The hospital records usually do not indicate that the operation was not performed by the family physician. In other words, fraud is perpetrated in a number of ways; the physician and hospital are both open to suit and collection of damages.

Payment of a Salary to Referring Physician. In an attempt to avoid the designation "fee-splitting," some physicians have organized a "clinic" and placed referring physicians on a salary which would be about equal to the amount due as refund for the split for fees collected from patients sent to the "clinic." These physicians are trying to hide under the cloak of the ethical procedure of employment by salary of physicians by a clinic. However, in the true clinic the physician is hired, usually full time, for care extended patients, regardless of the source of referral. Moreover, in the ethical clinic there is no element of inducement.

Abuse of First Assistantship Privilege. It is obvious that a surgeon must have a first assistant; he should be sufficiently well trained to perform this duty efficiently. In hospitals which are approved for the training of residents this duty or privilege is assigned to the resident. When a resident is not available, some other physician will have to be secured for operations which are of sufficient magnitude to require an assistant. The surgeon is expected to obtain the services of the best qualified physician or surgeon available. If the assistant is not the referring physician, he may send his bill to the patient, or he may be paid directly by the surgeon, even without the knowledge of the patient (9). If the assistant is the referring physician, he must be paid by the patient, and not by the operating surgeon. Under such circumstances the amount of the fee for assisting must be a fair charge equivalent to the amount paid the assistant when he is not the referring physician. It is entirely unethical for the surgeon to overstate the value of assisting to the patient so that he

will pay an exorbitant fee. If the referring physician should send a bill larger than a just one for service rendered, it is classified as an overcharge and actually is a form of fee splitting if part goes to the referring physician.

Unjustified Operation. This "is one in which either the indications were inadequate, or the procedure was one which is contrary to generally accepted surgical practice" (7). At times there may be a controversy as to just when an operation is justifiable, because error in diagnosis may be made by even the best of physicians. To pass judgment on the justification of a given operation, accredited hospitals have an audit, or tissue, committee to review the data. The greatest abuse is observed in removal of normal uteri and normal appendices. The terrible injustice to the patient of performing a needless operation needs no supporting arguments.

Excessive Fees. An excessive or exorbitant fee may be defined as one "greater than the patient is reasonably able to pay, or higher than justified by the service rendered" (7). Unfortunately, there is no prescribed way in which a standard fee can be set for an operation. The skill required to perform a certain operation may be greater than that required for the same operation in another patient; moreover, the ability of the patient to pay must be considered, because a patient with a low income should not be charged even the average fee. A surgeon of great experience may feel, and justifiably so, that his services are worth more than those of an inexperienced surgeon. The family physician often complains that the surgeon charged so much that the patient did not have enough money left to pay him; this may be a legitimate complaint, because the patient tends to pay the surgeon first, and to pay the referring physician if and when he accumulates money to do so.

RELATIONSHIP OF PHYSICIAN TO PHYSICIAN

There is no profession in which the members work in close contact with each other as much as in the medical profession. This intimacy makes it essential that the physician learn how to get along with his colleagues in the interest of the best care of the patient. The secret of the ability to get along with people is the application of the "Golden Rule." Allied to this philosophy is the axiom that one should not openly criticize his colleagues, but should make a constant effort to treat them with thoughtfulness as friends to be enjoyed and helped, rather than as competitors to be overcome or eliminated. When it is necessary for a physician to be out of town, it is customary to have another physician take care of his patients. The latter should, of course, return the patients to the former when he is again available.

During *consultations* certain important phases of conduct arise and should be clarified. In the first place, consultation is an important phase of medical practice and should be used more often. The knowledge available in medicine is so tremendous that no one person can possibly possess all of it; even the specialist in a comparatively narrow field cannot feel that he is completely informed in that subject. The old adage "two heads are better than one" certainly applies to medical problems. If the physician is in doubt about certain important phases of the patient's illness, he should ask permission to call in a consultant. If the patient appears unhappy and dissatisfied with the physician's advice and care, it is highly desirable to ask the patient if he would like to have a consultant see him. After the consultant has completed his examination, he should retire with the physician in charge to discuss the patient's condition. After they have had their conference, they should present the results of their deliberations to the patient or his relatives. It is customary for the consultant to do this in the presence of the physician in charge, since the consultant is actually employed by the patient. The consultant must not dishonestly agree with the physician in charge just for the sake of being friendly, if he feels the diagnosis or therapy is erroneous. On the other hand, the consultant should not criticize the physician in charge for inability to arrive at a solution to the medical problem, because often the solution is not apparent until all the data have accumulated. In most cases a common ground for therapy can be reached. An awkward situation might arise if the consultant and the physician calling for aid could not agree on a plan for further care. Usually in such circum-

stance a third physician is called in, or the first consultant withdraws after being given the opportunity to present his views to the patient or relatives in the presence of the physician in charge.

It should be emphasized that no patient "belongs" to the physician as a property right; *the physician is actually hired by the patient*, who may go to as many physicians as he likes. However, medical principles require that for the good of the patient he should not have two physicians at the same time when neither knows what the other is advising and prescribing. If a patient leaves one physician to go to another physician, that is his privilege. The second physician under such a circumstance has no obligation to send the patient back. Indeed, the first physician should cooperate by sending to the second physician on request any data he has.

RELATIONSHIP OF PHYSICIAN TO THE PATIENT

Certain professional characteristics are necessary for a physician's success. Two of them are very essential: 1. honesty, and 2. willingness to practice the "Golden Rule."

In his contact with the patient many of the physician's attitudes are related to his personal characteristics, others to medical activities. In the first place, he should be willing to listen to the patient and be considerate of his feelings; he must be sympathetic. He should be dignified, but friendly. It is essential that he get acquainted with the patient, but too frequent or close social contacts are undesirable for numerous reasons unless they have existed before. A physician must not drink alcoholic beverages during working hours. Excessive drinking after hours is likewise highly undesirable because the physician never knows when he may be called on an emergency; in fact, persistent heavy drinking will ruin the physician's career. The foul breath of excessive smoking is disagreeable to the patient and makes a bad impression.

The physician should be honest in his expressed opinions, yet he should not divulge knowledge which might be detrimental to the patient, particularly if the patient is overly apprehensive. The physician must not be guilty of making misleading and inaccurate statements about the patient's disease to create a good impression, or for any other reason, because discovery of inaccurate statements by the patient will lead to loss of confidence; *moreover, it is dishonest. Do not* criticize fellow physicians, since this amounts to a method of self-criticism, and is usually interpreted by the patient as a weakness in personality.

The physician must be willing to spend time with the patient. He should explain the patient's disease in terms which the patient can understand (Truman, 1). The physician *may demonstrate his knowledge* of a disease, but must not brag.

The physician should be a good psychologist so that he may detect diseases which are related to personal problems, because the patient, himself, may be entirely unaware of this relationship. Accordingly, the physician *must be sufficiently astute and intelligent* to suspect the influence of family or social problems on the disease or patient's complaints. It may be necessary to scrutinize the personal and social problems of the patient, and to determine the extent to which he has been worrying about family or financial matters. Moreover, the physician must try to evaluate the patient's sincerity; often through false modesty the patient will give misleading or dishonest answers to questions.

The physician must not lose his temper in his contact with patients. He must remember that the patient is ill, and the situation is comparable to an axiom in business, namely, "the customer is always right." This does not mean that the physician must bow to the patient's wishes, but implies that he must be tolerant. There are many ways of saying, "no," without being abrupt.

When the patient has a serious or perhaps incurable disease, such as cancer, numerous problems arise which require much diplomacy and tact.

Should the patient be told he has a serious or hopeless disease? The answers to such questions as how much the physician should *tell the patient* are exceedingly important, although difficult of solution. There is no categorical answer to the question, "Should you tell the patient he has a cancer?" If the patient is a busy *executive, who must have*

an approximation of his life expectancy to plan for future possible activities, he must be told he has a cancer or malignant disease. However, the doctor should be sure to tell the patient the truth. There is no excuse for telling a patient he is going to die in six months, or at any specified time, particularly since no one can predict the exact duration of life in the hopeless stages of cancer, heart disease, etc. Moreover, supposedly hopeless cancer may occasionally cease its growth and, in fact, spontaneously regress. If the tumor is inoperable, the physician can tell the patient the prospects are not good, but to be hopeful. If the tumor has been removed by surgical or other means, he can inform the patient that the outlook should be very optimistic. A business executive usually is sufficiently mature to accept news of this type without losing his equilibrium. He does not fear death nearly as much as a young person. Moreover, the problems with which an older individual has been confronted have hardened him to the sad facts of life. He can, accordingly, adjust rapidly and effectively.

If the patient is young and apprehensive, it may not be wise to tell him he has a cancer or malignant growth. If an operation is indicated, the physician can tell the patient he has a growth which must be removed. If he asks a pointblank question, such as, "Is it cancer?" the physician can give an indirect answer, saying he must wait for microscopic sections; however, one should remember that candor is the best policy. It is the way truth is told that is important. After the growth has been removed the physician can then tell the patient that the question of the degree of malignancy becomes of less importance since no more trouble is expected. As Elman (10, 11) has stated, when patients are being treated for tumors most of them will accept a reasonable explanation concerning their illness and not demand specific answers. If the medical student is asked by the patient whether or not he has cancer, the answer should be very cautious since the student may not have the experience and tact to discuss such a vital point with the patient.

RESPONSIBILITY TO THE COMMUNITY

One of the physician's first responsibilities when starting practice in a community is to join the local medical society and take part in its activities. He should make sure that the society exerts all possible effort to treat the public fairly. The medical society should have a Grievance Committee, or a committee of this type, the function of which should be to listen to patients' complaints, especially concerning fees. If the physician does not think the function of the medical society is being carried out correctly, he should not stay away from meetings and criticize privately; it is much more effective to attend the meetings and try to correct the erroneous thought or action openly.

The physician must always remember that people are justifiably interested in and curious about their health and medical problems. There can be no doubt that life is the most valued of a person's worldly possessions. Accordingly, our actions must be governed by that fact. The physician should attempt to satisfy this need not only by action but by word. He need not explain the disease or symptoms at great length; often a few simple sentences will suffice. But he must not adopt a policy of mystery or indifference. The public, as well as the medical profession, must realize that health is a responsibility of both. Mutual effort must be provided in improving circumstances related to health.

Medical insurance should be encouraged. The types of policies are improving from year to year, but, for some unexplained reason, the insurance companies have been very slow in writing and publicizing the most valued and important of all policies, namely, the one to protect the patient against a medical catastrophe. The failure to extend catastrophe insurance is partly responsible for the government's efforts to enter the medical insurance field.

MALPRACTICE AND MEDICOLEGAL ASPECTS OF PRACTICE

Suits for malpractice are increasing. Every physician should have malpractice insurance. To protect himself against possible suit, he should pay particular attention to the type of care given the patient. Everybody, including lay individuals, realizes the human body is so intricate that no physician is expected to know all its mechanisms of function in health and disease. Courts of law are aware of this,

and consequently not all errors are subject to suit. In general, the plaintiff must prove negligence or failure to use the average care, skill, and judgment exhibited in the practice of medicine in that community. Rarely is the wrong diagnosis sufficient to justify a suit, although there are such cases on record. Numerous phases of malpractice have been studied by the American College of Surgeons, and an important feature not sufficiently realized is pointed out by the following quotation from their publications (8):

> Yet the fact of the matter is that the malpractice claim, like charity, begins at home in many cases. It is in the surgeon's office or consulting room, and not in the hospital, that the seeds of malpractice claims are most commonly sown, for it is here that the doctor-patient relationship is established. The doctor-patient relationship is the soil in which dissatisfaction may take root and flourish or wither and die, depending on the surgeon's conduct.

Among the hazards often overlooked, the following factors have been emphasized by underwriters of the Professional Liability Insurance Program of the American College of Surgeons (12), and by malpractice authorities generally:

1. Carelessness or incompetence of office assistants
2. Destructive or unethical criticism of the work of other physicians
3. Improper conduct of physical examinations
4. The overoptimistic prognosis
5. Admissions of failure in connection with treatment
6. Failure to suggest consultation when results are unsatisfactory or when the patient shows signs of dissatisfaction or impatience
7. Office equipment that is obsolete or in poor working condition
8. Poorly planned or executed billing procedures, and excessive bills

Good records are very important in protecting the physician against suit. Accordingly, the physician must maintain detailed data in his office records and insist that data in hospital records be complete.

Nonunion and malunion of fractures are perhaps the most common causes of suit, even though the treatment rendered the patient may not have been erroneous or lacking in good judgment. Foreign bodies left in the wound at operation are likewise common causes for suit. Since, with few exceptions, the surgeon will have difficulty proving he has utilized average care under such circumstances, the verdict is apt to be favorable to the patient. Instruments left in a body cavity at the time of operation can be detected by x-ray. So also can sponges be detected by x-ray, since operating room sponges now are tagged with material impervious to the x-ray. The physician may be able to remove the sponge without knowledge of the patient, but with very few exceptions such action is not to be condoned, since the physician is then liable for fraud in addition to loss of the sponge in the wound.

It may be of slight comfort to know that the law will usually be on the side of the physician who has acted conscientiously and competently in fields in which he is qualified.

EUTHANASIA

Euthanasia may be defined as the planned destruction of life for what is called medically justified reasons. However, it is a dangerous practice which cannot be approved by the medical profession, even though it often appears cruel to allow a patient with a hopeless disease to live and suffer. There are numerous reasons for not approving destruction of life, even in circumstances in which recovery seems impossible (13). In the first place, a cure might be discovered at any time for what is a seemingly hopeless disease. In the second place, the practice of euthanasia inflicts a heavy blow on our moral responsibilities. The big question is: who is to decide what is hopeless, and who shall die? What is to prevent the physician from being influenced by ulterior motives, such as the hatred of a member of the family who no longer wants the patient to recover? Moreover, the courts have ruled that euthanasia is illegal. The physician who practices it does so with the possibility of a death verdict in court. This does not mean that adequate control of pain and suffering with the use of large and even sublethal dosage is not justified and even indicated. No patient should be permitted to suffer merely to prolong his life, already threatened by a fatal disease.

RELATIONSHIP OF PHYSICIAN TO HOSPITAL

Most hospitals permit only staff members to bring patients into the hospital. In determining the membership of its staff, the hospital is autonomous. However, to meet the approval of the medical profession, certain standards have been set. Years ago, the American College of Surgeons initiated a program by which hospitals could be accredited after meeting certain standards. As the number of hospitals increased throughout the country, this work became too complicated, and too expensive for one organization to execute. Accordingly, the Joint Commission on Hospital Accreditation was formed to attain this very important objective. This Commission is administered and supported by four major societies, American College of Physicians, American College of Surgeons, American Hospital Association, and American Medical Association.

Hospital accreditation is very important in the health of the community, because the welfare of the hospitalized patient depends to a great extent upon the standards maintained in that hospital. Accordingly, it is essential that the physician support the hospital in its efforts to support high standards, which are readily measured in terms of accreditation. If a hospital is not accredited, the staff must make all effort to improve the facilities so that it may be approved by the Joint Commission on Accreditation. Hospitals are inspected in various ways. Important are the administrative and professional organizations. The laboratory facilities, record room and other ancillary functions are investigated. Good medical records must be maintained by the medical staff. The services of a pathologist must be provided. All tissue removed at the operating-room table must be examined. The hospital must maintain a pharmacy, radiology department, and medical library. The staff must obtain an acceptable percentage of autopsies. A minimum attendance at hospital meetings is required.

As stated previously, the hospital itself is autonomous in that the Hospital Board has the primary authority in all appointments and details, so long as prerequisites mentioned above are met. However, certain problems not related to accreditation are important. One of these is the question as to who may have surgical privileges. It should be emphasized that neither the various Boards of Surgery nor the American College of Surgeons has made any statement whatsoever as to who shall operate in individual hospitals. That decision is up to the hospital itself. Often the hospital sets up various classifications in this regard; e.g., full operating privileges and limited operating privileges. The assignment of a house staff physician to either of these two groups is determined by a hospital committee. However, such a plan is far from ideal, since serious problems commonly present themselves at the operating table, although a simple operation was contemplated. For example, a physician may perform a celiotomy for appendicitis when the real cause of symptoms is a carcinoma of the right colon. Under such circumstances, the surgeon should be allowed to perform the correct surgical procedure and not have to subject the patient to two operations by closing the abdomen and having a competent surgeon do the definitive operation at a later date.

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